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WHAT IS LIGHT?[1]

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FROM the time that the ancient Greeks told each other about the shafts of light shot by Apollo, men have concerned themselves with what light is. Together with its sister problem, the nature of matter, this question presents the fascination of a fundamental mystery. During the last generation a rich mine of new information regarding light has been worked, and the remarkable discoveries that have thus appeared have seemed to make the subject a suitable one to present before the Society of Sigma Xi. Yet in spite of this new information light remains as perhaps the darkest of our physical problems, and as such may well be reviewed before the Physics section of the American Association.

As long ago as the seventeenth century, Newton defended the view that light consists of streams of little particles, shot with tremendous speed from a candle or the sun or any other source of light. At the dawn of the nineteenth century, however, experiments were performed which were thought to give positive evidence that light consists of waves. Maxwell interpreted them as electromagnetic waves, and in such terms we have ever since been explaining light rays, X-rays and radio rays. We have measured the length of the waves, their frequency and other characteristics, and have felt that we know them intimately. Very recently, however, a group of electrical effects of light has been discovered for which the idea of light waves suggests no explanation, but whose interpretation is obvious according to a modified form of Newton's old theory of light projectiles.

REVIEW OF THE VARIOUS ELECTROMAGNETIC RADIATIONS

When the physicist speaks of light he thinks not only of those radiations which affect the eye. He refers rather to a wide range of radiations, similar to light in essential nature, but differing in the quality described variously by the terms color, wave-length or frequency.

At one end of this series of radiations are the wireless, or radio rays, with which in recent years we have become so familiar. There is an important point regarding these rays which I should like to call to your attention. When one strikes the strings of a mandolin, they are set into vibration, and produce up in the surrounding air the waves which affect our ears and cause the sensation of sound. Investigation shows that the sound waves in the air vibrate with the

[1] Address given jointly as the annual Sigma Xi address and as the retiring vice-presidential address of the physics section of the American Association for the Advancement of Science. The address was presented at a general session of the American Association on the evening of December 28.

same frequency—the same number of times per second—as do the strings on the mandolin. In precisely the same way, when electrically charged condensers are discharged, an oscillation of the electric charge is set up which gives rise to electric waves just as the vibrating string produced sound waves. These electric waves are caught by an electric ear at the rear of the room, and are there transformed through a loud speaker into the noise which offends your tone-conscious ears.

The emitted electric waves have the same frequency as the oscillating source. Though visible light is known to be essentially the same kind of thing as these electric waves, we have long sought in vain for any oscillator which would emit light waves having the same frequency as that of the oscillating source. It was only when Heisenberg introduced a new kind of mechanics, differing radically from the classical ideas of Newton, that we found that the atom vibrates with certain "overtones" whose frequency is that of the light waves which come from it. This is one of the serious difficulties with the wave conception of light which could only be solved by a fundamental change in our ideas regarding how things work.

Measured in terms of the length of a wave, electric waves extend from many miles in length down through the radio waves of say 300 meters, to the very short waves resulting from tiny sparks, which may be no more than a tenth of a millimeter in length. These rays overlap in wave-length the longest heat waves radiated by hot bodies, and may be detected and measured by the same instruments. A familiar source of such heat rays is the reflector type of electric heater, the kind that warms one side of us in a chilly room. The greater part of these heat rays are intermediate in wave-length between the shortest electric waves and visible light. Such a heater, however, glows a dull red, showing how its rays extend into the visible region.

Ordinary visible light is well represented by the radiation from a carbon arc. I shall pass its rays through a lens and prism, and project them onto this screen. We see how it is made up of rays of many colors, from red to violet, which the prism has separated from each other. Beyond the red end of the spectrum lie the heat rays. Indeed if we should place a radiometer just beyond the red end of the spectrum, we should find it strongly affected by the heat rays from the arc. The question arises, are there similar radiations beyond the violet which we are unable to see?

In order to answer this question, let me bring up a fluorescent screen of platinum barium cyanide. Notice the brilliant green glow extending far beyond the violet light on the ordinary screen. Evidently our failure to see light in this region is not because there is no light, but because our eyes are insensitive to rays of this type. The fluorescent screen changes their color so that we can see them. These are the ultra-violet rays, of which we have heard so much recently in connection with summer sunshine and prevention of rickets.

As one goes farther into the ultra-violet the rays become rapidly absorbed by air, and can be studied only in a vacuum. But at still shorter wave-lengths the rays are again less readily absorbed as we approach the region of X-rays. A high tension transformer shoots the electrons at high speed from the hot wire cathode against the tungsten target and these X-rays are emitted (Fig. 1). It is like shooting a rapid fire gun at a steel plate. The bullets represent the electrons shot from the cathode, and the noise resulting when the bullets bang against the plate represents the X-rays.

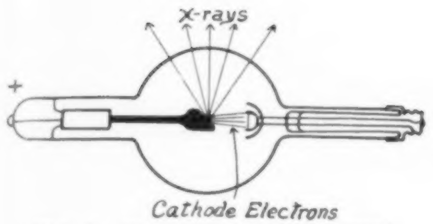


FIG. 1. COOLIDGE X-RAY TUBE
ELECTRONS SHOT FROM THE CATHODE AGAINST THE TARGET PRODUCE THERE X-RAYS, WHICH ARE LIGHT OF VERY SHORT WAVE-LENGTH.

Just as in the case of ultra-violet light, these X-rays do not affect our eyes. Their existence can, however, be shown by placing in their path the same screen which we used to detect the ultra-violet rays. Notice how it lights up when I apply the voltage from the transformer. That these rays are of the same nature as light is shown by the fact that we have found it possible to reflect and refract them, to polarize and diffract them. They are indeed light of ten thousand times shorter wave-length.

One of the most important properties of X-rays is their ability to ionize air and make it electrically conducting. Let me show this by the following experiment. You see projected on the screen the gold leaf of an electroscope. Notice, when I turn on the X-rays, how quickly the leaf falls, showing that the electroscope has lost its charge. This is due to the breaking up by the X-rays of the oxygen and nitrogen atoms in the air. Precisely the same thing happens to the atoms in one's body when in the path of X-rays. This it is which makes possible X-ray burns and X-ray therapy.

Such ionization can also be produced by the gamma rays from radium. Let us charge the electroscope again. This time instead of turning on the X-rays, we shall bring up a small tube containing a milligram of radium. Again the leaf falls as the electroscope loses its charge. These rays are much less intense than the X-rays, as is shown by the slowness with which the leaf drops. They are, on the other hand, much more penetrating. Whereas X-rays may be half absorbed in an inch of water, it takes a foot of water to absorb half of these gamma rays from radium, corresponding to the much shorter wave-length of the radioactive rays.

But the end is not yet. There exists a kind of highly penetrating radiation which is especially prominent at high altitudes, and is supposed to come from some source outside the earth. These *cosmic rays*, as they are called, will penetrate ten or twenty feet of water before they are half absorbed. Unfortunately I can not show them to you here, for it would take all night for such rays to make an appreciable effect on our electroscope.

In Fig. 2 we see graphically how these different rays are related to each other. At the extreme left I have arbitrarily started the spectrum at a wave-length of eighteen kilometers, which is the wave-length of certain transatlantic wireless signals. There is no reason why longer waves could not be produced if desired. The electric waves continue in an unbroken spectrum down to 0.1 mm, rays recently studied at Cleveland by the late Dr. Nichols and Mr. Tear. Overlapping these electric waves are the heat rays, which have been observed from about .03 cm to .000,03 cm, including the whole of the visible region. The heat rays in turn are overlapped by the ultra-violet rays, produced by electric discharges; and these reach well into the region described as X-rays. Beyond these are in turn the gamma rays and the cosmic rays. Thus over a range of wave-lengths of from 2×10^{-13} cm to 2×10^{-6} cm there is found to be a continuous spectrum of radiations, of which visible light occupies only a very narrow band.

The great breadth of this wave-length range will perhaps be better appreciated if we expand the scale until the wave of

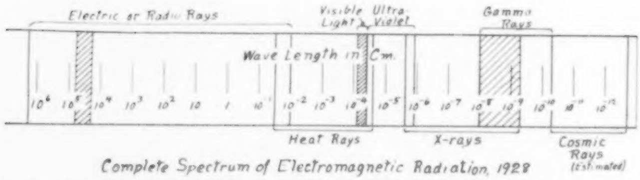


FIG. 2. COMPLETE SPECTRUM OF ELECTROMAGNETIC RADIATION

ON A LOGARITHMIC SCALE. VISIBLE LIGHT IS ONLY A SMALL BUT VERY IMPORTANT PART OF THIS SPECTRUM.

a cosmic ray has a length equal to the thickness of a post card. The longest wireless wave would on this scale extend from here to the nearest fixed star.

When the physicist speaks of light, he refers to all the radiations included in this vast range. We believe that they are all the same kind of thing, and that anything which may be said about the nature of the rays in one part of this region is equally true of the rest.

It will perhaps be profitable to pause at this point and ask ourselves what type of evidence we may hope to get regarding the nature of radiation. When men began to inquire regarding what sound is, it was possible for them to feel the vibrations of the sounding bodies in many cases, and sometimes even to feel the vibrations set up by the sound itself. The sound thus *acts as if* it were a wave motion. When later we found it possible to photograph the shadow cast by a sound wave, no one could reasonably question the existence of the waves. There seems to be no possibility of seeing or photographing a light wave or light corpuscle as we can a sound wave or a bullet in flight. If, however, light consists of waves, it should act as waves do; and if it consists of corpuscles it should act as do corpuscles. This is probably as far as we can go.

Light Consists of Waves

There are many ways in which light acts like a wave in an elastic medium. Such elastic waves move with a speed which is the same for all wave-lengths and all intensities, just as does light. Waves, like light rays, can be reflected and refracted. The polarization of light is a property characteristic of the transverse waves in an elastic solid. It is true that if one examines the constancy of the speed of light in detail, difficulties arise; for it is found that its speed is the same relative to an observer no matter how fast the observer is going. This would not be true if light were a wave in an ordinary elastic medium. Maxwell's identification of light as electromagnetic waves, however, removes this difficulty.

The crucial test for the existence of waves, however, has always been that of diffraction and interference. You have doubtless at some time amused yourselves by dropping pebbles into a pond, and watching the ripples spread out. Perhaps two pebbles fell in at once. In some places the crests of the two sets of ripples would come together and reinforce each other. Elsewhere perhaps the crests of one set of ripples would fall on the troughs of the other and both would be neutralized. Suppose we should drop a whole row of pebbles at once into the pond. The effect would be like that shown in Fig. 3.

In this figure we imagine a series of waves passing through a succession of openings in a grid. After passing through, the crests of the emerging wavelets recombine to form a new wave going straight ahead. But in addition, the wavelet just emerging from one

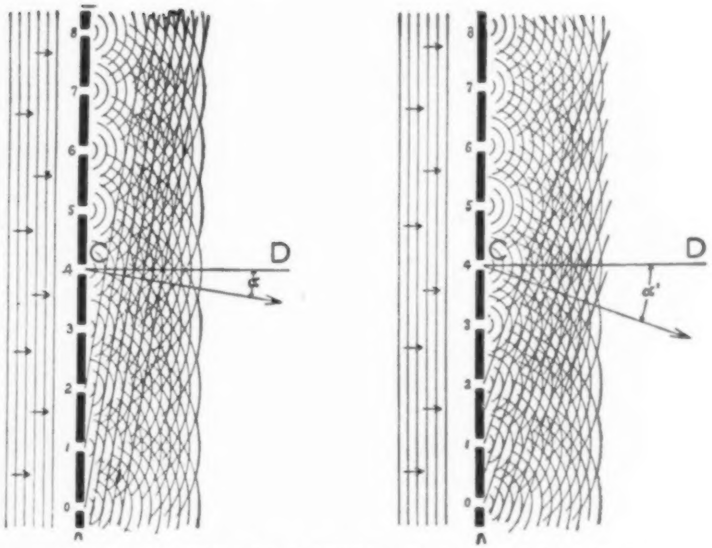


FIG. 3. DIAGRAM OF THE DIFFRACTION OF WAVES BY A GRID.

opening may combine with the first wave from the next opening, the second from the next, and so on, forming a new wave-front inclined at a definite angle to the first. The angle between these two waves, as you see from this diagram, is determined by the distance between successive waves—*i.e.*, the wave-length—and by the distance between successive openings in the grid. The figure at the right shows how the emergent wave may combine with the second wave from the adjacent opening, the fourth from the second opening, and so on, and form a wave-front propagated at a larger angle.

That such a variety of wave formation is not purely imaginary is shown in Fig. 4, which is a photograph of ripples on the surface of mercury, taken after they have passed through a comb-like grid. Notice how one group of waves combines to form a wave-front going straight ahead. But in addition, on either side of the central beam, we find two beams forming where the paths from successive openings in the grid differ by one wave-length. Out at a large angle we see even the second order of the diffracted beam.

If we were unable to see the separate waves, but knew the kind of grid through which the beam of ripples had passed, not only could we say that this is the way the beam should be split up if it consists of waves, but we could even tell what the wave-length of the ripples must be in order to give these particular angles between the diffracted beams.

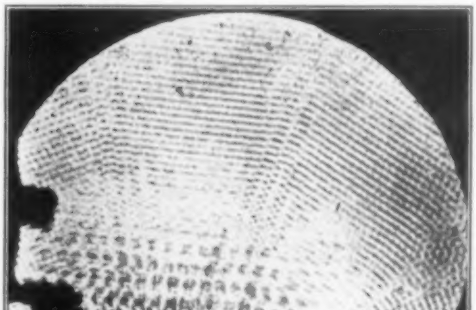


FIG. 4. PHOTOGRAPH OF MERCURY RIPPLES DIFFRACTED BY A GRID.

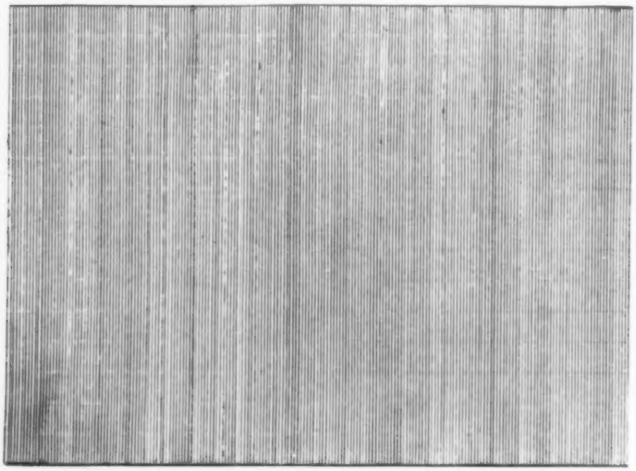
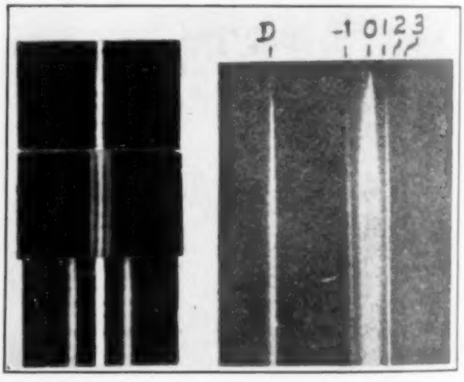


FIG. 5. A PATTERN OF 200 REGULARLY SPACED LINES
WHICH WHEN PHOTOGRAPHED ONTO A LANTERN SLIDE FORMS A DIFFRACTION GRATING FOR EXPERIMENTS ON LIGHT.

We may perform the same experiment with a beam of light. In Fig. 5 is shown a set of some two hundred vertical lines. If these lines are photographed onto a lantern slide, they form a grid through which a beam of light may be made to pass. The upper part of Fig. 6 shows a beam of light as projected from a projection lantern. The middle part of the figure shows the same beam of light, but this time projected through such a lantern slide grid having about one hundred lines to the inch. See how the original spot of light is split into three, a bright one in the center—the direct ray, and a diffracted ray on either side. It is just as in the case of the mercury ripples passing through the grid.

If this is really a case of the diffraction of waves, as we have supposed, if a grating with lines closer together is used, the separation between the diffracted images should be correspondingly greater. The lower part of Fig. 6 shows our beam of light projected this time through a grid photographed with about three hundred lines to the inch. The separation of the diffracted beams is much greater. When these diffracted images are thrown on a screen, one can see that their outer edges are red and their inner edges blue. This means that



FIGS. 6 AND 7. DIFFRACTION OF LIGHT AND X-RAYS
(LEFT.) THE UPPER PORTION IS THE DIRECT BEAM, THE MIDDLE PORTION THAT THROUGH 100 LINES TO THE INCH, AND THE LOWER PORTION PHOTOGRAPHED THROUGH A GRID OF 330 LINES TO THE INCH. (RIGHT.) DIFFRACTION PATTERN OF X-RAYS. D IS THE DIRECT BEAM, O THE DIRECTLY REFLECTED BEAM, AND THE OTHER LINES ARE DUE TO DIFFRACTION.

red light is of the greater wave-length. In fact we could easily from this experiment tell what the wave-length of light is: the distance from the central image to the diffracted image is to the distance from lantern to the screen as the wave-length of the light is to the distance between the lines on the grating. When one carries through the calculation, he finds that the wave-length of light is about one fifty thousandth of an inch.

If we can rely on such a test, light must consist of waves.

Diffraction of X-rays. Precisely similar experiments can, however, be done with X-rays. Fig. 8 shows how we do it. In place of the projection lantern we here have an X-ray tube and a pair of slits. The slide with the lines on it is replaced by a polished mirror on which lines are ruled fifty to the millimeter. Instead of the screen we use a photographic plate. The resulting photograph is shown in Fig. 7. When the ruled mirror is withdrawn we have the single vertical line D. With the grating in place we see a bright central reflected image O with companions on either side. Thus X-rays can also be diffracted, and must therefore, like light, consist of waves.

Light Consists of Particles

For a hundred years no one had seriously questioned the truth of the wave theory. At the close of the last century even the difficulty of supplying a suitable oscillator to give rise to the

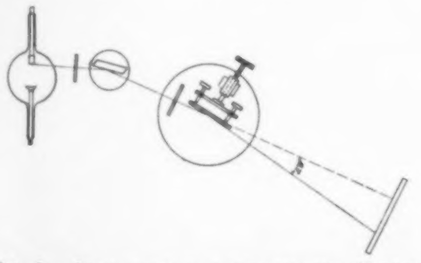


Fig. 8. Apparatus for diffracting X-rays from a ruled reflection grating.

light waves seemed about to disappear through the discovery of electrons which seemed exactly suited to fill the need. But in 1900 Planck published the results of a long study of the problem of the radiation of heat and light from a hot body. This difficult theoretical study, which has stood the test of time, showed that if a body when heated is to become first red hot, then yellow and then white, the oscillators in it which are giving out the radiation must not radiate continuously as the electromagnetic theory would demand. They must rather radiate suddenly little portions of energy. The amount of energy in each portion must further, according to Planck, be proportional to the frequency. This is the origin of the celebrated "quantum" theory.

On account of the difficult character of the reasoning involved in Planck's argument, his conclusions carried weight only among those who were especially interested in theoretical physics. Among these was Einstein, who called attention to the fact that Planck's conclusions would fit exactly with the view that the radiation was not emitted in waves at all, but as little particles each possessing a portion of energy proportional to the frequency of the oscillator as Planck had assumed.

Einstein and the photoelectric effect. An opportunity to apply this idea was afforded by the photoelectric effect. It is found that when light as from an arc falls upon certain metals, such as zinc or sodium, a current of negative electricity in the form of electrons escapes from the metallic surface. This photoelectric effect is especially prominent with X-rays, for these rays eject electrons from all sorts of substances. In Fig. 9 you see one of C. T. R. Wilson's photographs of the trails left by electrons ejected by X-rays passing through air and a sheet of copper. These electrons, shot out of the air and the metal

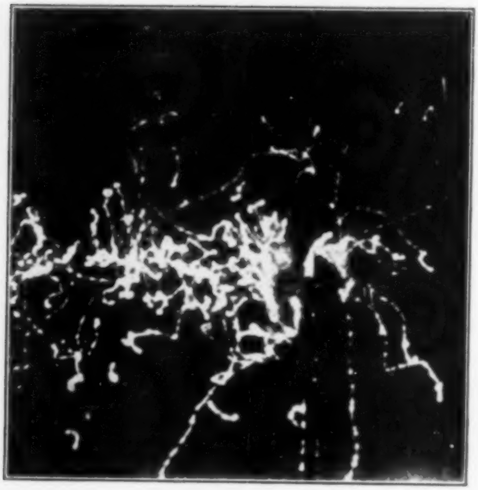


FIG. 9. PHOTOGRAPH OF THE TRACKS OF PHOTO-ELECTRONS EJECTED FROM COPPER BY X-RAYS (WILSON).

by the action of the X-rays, are the X-ray photoelectrons.

The most remarkable property of these photoelectrons is the speed at which they move. We have seen, as in Fig. 10, that X-rays are the waves produced when the cathode electrons bombard a metal target inside the X-ray tube. Let us suppose that a cathode electron strikes the target at a speed of a hundred miles a second (they move tremendously fast). The resulting X-ray, after passing through the walls of the X-ray tube and perhaps a block of wood, may eject a photoelectron from a metal plate placed on the far side. The speed of this photoelectron is then found to be almost as great as that of the original cathode electron.

The surprising nature of this phenomenon may be illustrated by an experience which I had in my early boyhood. During the summer vacations my father would take our family to a lake in northern Michigan. My older brother, who is in the audience this evening, with several of the older boys, built a diving pier around the point a half a mile away from the camp, where the water was deep. Fearing lest something should happen, my mother would not allow us younger boys to swim in this deep water. So we built a diving pier of our own in the shallower water in front of the camp. It so happened, one hot, calm July day, that my brother dove from his diving board into the deep water. The ripples from the resulting splash of course spread out over the lake. By the time they had gone around the point to where I was swimming half a mile away, they were of course much too small to notice. You can imagine my surprise, therefore, when these insignificant ripples, striking me as I was swimming under our diving pier, suddenly lifted me bodily from the water and set me on the diving board!

Does this seem impossible? If it is impossible for a water ripple to do such a thing it is just as impossible for an ether ripple, sent out when an electron dives into the target of an X-ray tube, to jerk an electron out of a second piece of metal with a speed equal to that of the first electron.

It was considerations of this kind which showed to Einstein the futility of trying to account for the photoelectric effect on the basis of waves. He saw, however, that this effect might be ex-

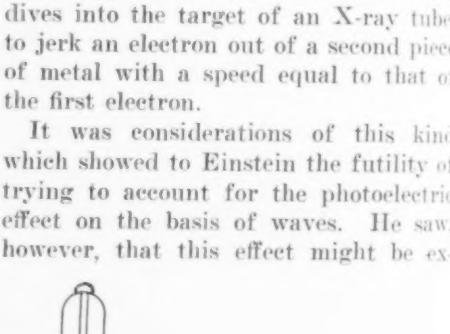


FIG. 10. THE SPEED OF THE PHOTO-ELECTRONS

EJECTED FROM THE METAL PLATE AT P IS ALMOST AS GREAT AS THE SPEED OF THE CATHODE ELECTRONS WHICH PRODUCE THE X-RAYS AT THE TARGET T.

plained if light and X-rays consist of particles. These particles are now commonly called "photons." The picture of the X-ray experiment on this view would be that when the electron strikes the target of an X-ray tube, its energy of motion is transformed into a photon, that is, a particle of X-rays which goes with the speed of light to the second piece of metal. Here the photon gives up its energy to one of the electrons of which the metal is composed, and throws it out with an energy of motion equal to that of the first electron.

In this way Einstein was able to account in a very satisfactory way for the phenomenon of the ejection of electrons by light and X-rays.

Peculiar X-ray echoes. Even more direct evidence that light consists of particles has come from a study of X-ray echoes. If you hold a piece of paper in the light of a lamp, the paper scatters light from the lamp into your eyes. In the same way, if the lamp were an X-ray tube, the paper would scatter X-rays into your eyes. If light and X-rays are waves, scattered X-rays are like an echo. When one whistles in front of a wall, the echo comes back with the same pitch as the original sound. This must be so, for each wave of the sound is reflected from the wall, as many waves return as strike, and the frequency or pitch of the echoed wave is the same as that of the original wave. In the case of scattered X-rays, the echo should similarly be thrown back by the electrons in the scattering material, and should likewise have the same pitch or frequency as the incident rays.

We measured the pitch of the X-ray echoes a few years ago at St. Louis, using the apparatus shown in Fig. 11. Rays from the target *T* of the X-ray tube were scattered by a block of carbon at *R*, and the pitch, or wave-length, of the echoed rays was measured by an X-ray spectrometer. By swinging the tube itself in

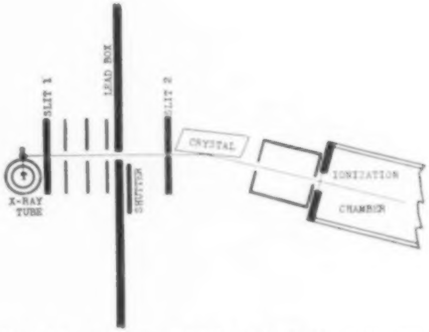


FIG. 11. THE WAVE-LENGTH OF THE X-RAYS

SCATTERED FROM A PIECE OF CARBON AT *R* IS MEASURED BY REFLECTION FROM A CRYSTAL.

line with the slits, it was possible to get a direct comparison with the wave-length of the original rays.

Fig. 12 shows the result of the experiment. Above is plotted the spectrum of the original X-ray beam. Below is shown the spectrum of the X-rays scattered in three different directions. A part of the scattered rays are of the original wave-length; but as you see, most of them are increased in wave-length. This would correspond to a lower pitch for the echo than for the original sound.

As we have seen, this change in wave-length is contrary to the predictions of the wave theory. If we take Einstein's idea of X-ray particles, however, we find a simple explanation of the effect. On this view, we may suppose that each photon of the scattered X-rays is deflected by a single electron, Fig. 13. Picture to yourselves a golf ball bouncing from a football. A part of the golf ball's energy is spent in setting the football in motion. Thus, the golf ball bounces off having less energy than when it struck. In the same way, the electron from which the X-ray photon bounces will recoil, taking part of the photon's energy, and the deflected photon will have less energy than before it struck the electron. This reduction in energy

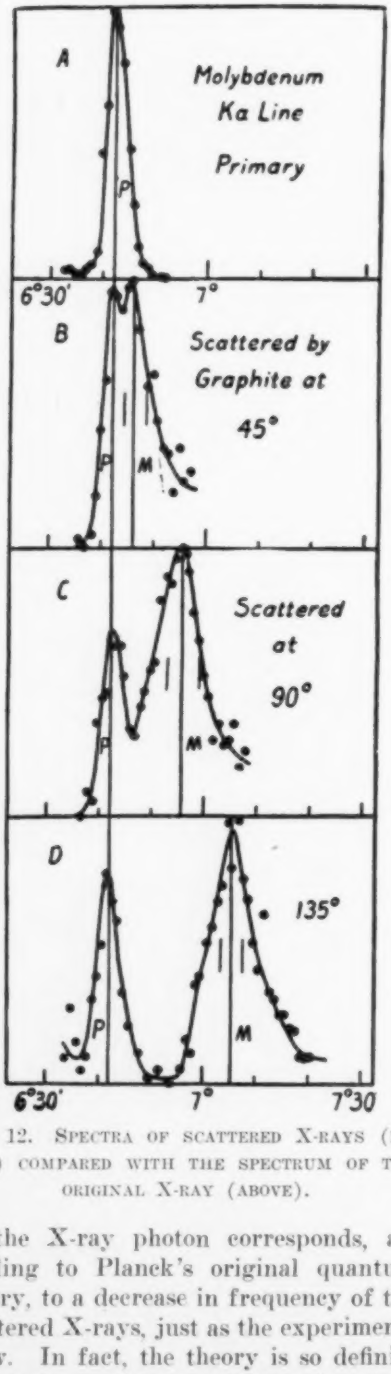


FIG. 12. SPECTRA OF SCATTERED X-RAYS (BELOW) COMPARED WITH THE SPECTRUM OF THE ORIGINAL X-RAY (ABOVE).

of the X-ray photon corresponds, according to Planck's original quantum theory, to a decrease in frequency of the scattered X-rays, just as the experiments show. In fact, the theory is so definite that it is possible to calculate just how great a change in frequency should

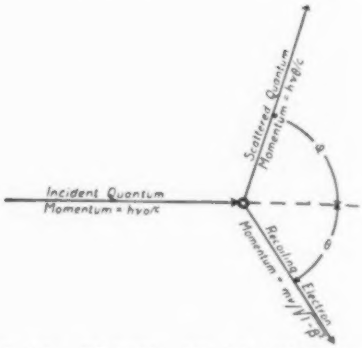


FIG. 13. RECOIL OF AN ELECTRON
WHEN AN INCIDENT X-RAY PHOTON GLANCES FROM AN ELECTRON, THE ELECTRON RECOILS FROM THE IMPACT, TAKING PART OF THE PHOTON'S ENERGY.

occur, and the calculation is found to correspond accurately with the experiments.

Playing billiards with photons and electrons. If this explanation is the correct one, it should however be possible to find the electrons which recoil from the impact of the X-ray particles. Before this theory of the origin of scattered X-rays was suggested, no such recoiling electrons had ever been noticed. Within a few months after its proposal, however, C. T. R. Wilson succeeded in photographing the trails left when electrons in air recoil from the X-rays which they scatter. Fig. 14 shows one of his typical photographs. The X-rays here are going from left to right. At top and bottom you notice the long trails left by two photoelectrons, which you recall have taken up the whole energy of a photon. In between are a number of shorter trails, all with their tails toward the X-ray tube. These are the electrons which have been struck by flying X-ray photons. Some have been struck squarely, and are knocked straight ahead. Others have received only a glancing blow, and have recoiled at an angle. Thus we have observed not only the loss in energy of the deflected photons, as shown by the lowering in

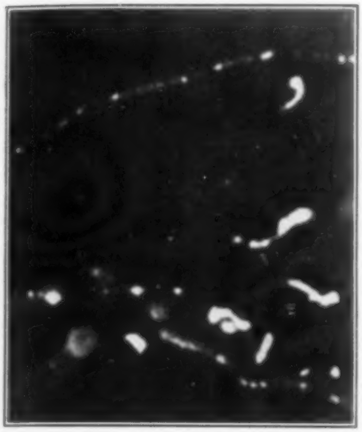


FIG. 14. RECOIL ELECTRONS
THE SHORTER TRACKS PROCEED ALMOST IN THE DIRECTION OF THE INCIDENT X-RAYS.

pitch of the X-ray echo, but we have found also the recoiling electrons from which the photons have bounced.

In order, however, to satisfy ourselves by a crucial test whether X-rays act like particles, an experiment was devised which would enable us to follow at the same time the photon as it is deflected by an electron, and the motion of the recoiling electron. In Fig. 15 we see at the left what we may call the X-ray gun, which shoots a few X-rays through a cloud expansion chamber. In this chamber is photographed the trail of every electron set in motion by the X-rays. So feeble a beam of X-rays is used that on the average only one or two recoil electrons will appear at a time. Let us suppose, as in the figure, that the electron struck by the X-ray particle recoils downward. This must mean that the X-ray particle has been deflected upward toward A. If this X-ray should strike another electron before it leaves the chamber, this event must occur at some point along the line OA. It can not occur on the same side as the recoil electron. If, however, the X-ray is a wave, spreading in all directions, there is no more reason why the second electron associated with the scattered ray should appear at A than at B. A series of photographs which shows the relation between the direction of recoil of the scattering electron *R* and the location of the second electron struck by the scattered X-ray, thus affords a crucial test between the conceptions of X-rays as spreading waves and X-rays as particles.

From a large number of photographs taken in this manner it has become evi-

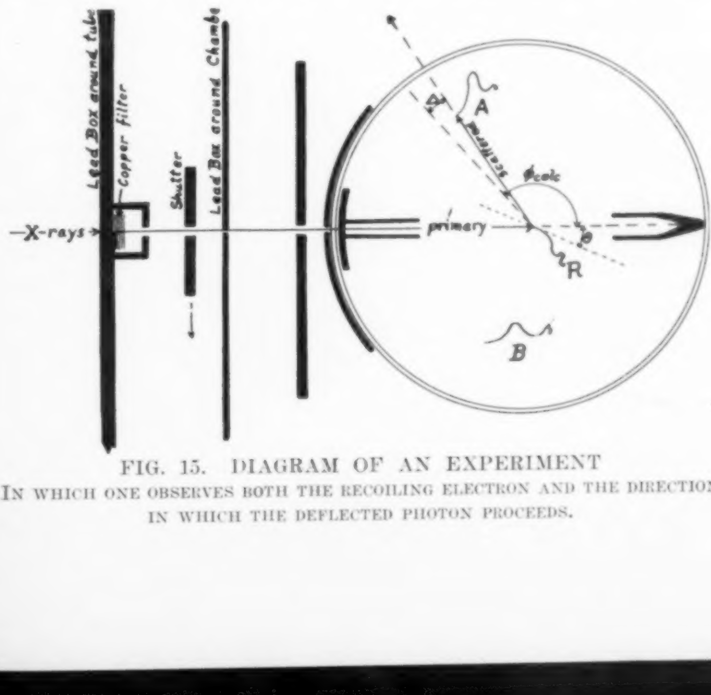


FIG. 15. DIAGRAM OF AN EXPERIMENT
IN WHICH ONE OBSERVES BOTH THE RECOILING ELECTRON AND THE DIRECTION IN WHICH THE DEFLECTED PHOTON PROCEEDS.

dent that an X-ray is scattered in a definite direction, like a particle. But if X-rays, so also all the rest of the family of electromagnetic radiations. It would thus seem that by these experiments Einstein's notion of light as made up of particles is established.

The Paradox of Waves and Particles

We thus seem to have satisfactory proof from our interference and diffraction experiments that light consists of waves. The photoelectric and scattering experiments afford equally satisfactory evidence that light consists of particles. How can these two apparently conflicting concepts be reconciled?

Electron waves. Before attempting to answer this question, let me call to your attenton the fact that this dilemma applies not only to radiation but also in other fundamental fields of physics. When the evidence was growing strong that radiation, which we had always thought of as waves, had also the properties of particles, L. de Broglie, of Paris, asked himself, may it not then be possible that electrons, which we know as particles, may have the properties of waves? An extension of Planck and Einstein's quantum theory enabled him to calculate what the wave-length corresponding to a moving electron should be. In photographs like Figure 9 we have ocular evidence that electrons are very real particles indeed. Nevertheless, de Broglie's absurd suggestion was promptly subjected to experimental test by Davisson and Germer at New York, and later by Thomson at Aberdeen and others.

Let me describe Thomson's experiments, which are typical of them all. You will recall that our crucial evidence for the wave character of light was the fact that light could be diffracted by a grating of lines ruled on glass. X-rays were diffracted in the same way; but before this had been shown possible, it was found that X-rays could be dif-

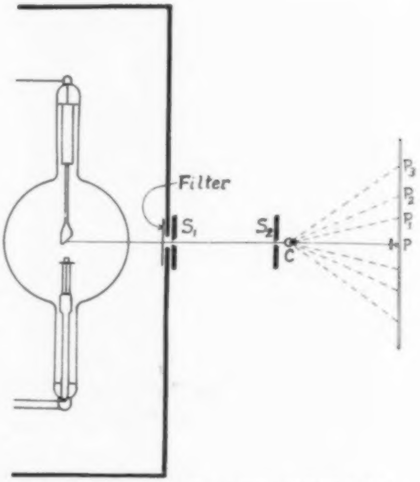


FIG. 16. HULL'S ARRANGEMENT
FOR DIFFRACTING A BEAM OF X-RAYS BY A MASS OF POWDERED CRYSTALS.

fracted by the regularly arranged atoms in a crystal. The layers of atoms took the place of the lines ruled on glass. Fig. 16 shows how this experiment has been done by Dr. Hull, at Schenectady. X-rays pass through a pair of diaphragms and a mass of powdered crystals placed at C, and strike a photographic plate at P. Rays diffracted by the layers of atoms in the crystal strike at such points as P_1, P_2, etc., giving rise to a series of rings about the center. If a mass of powdered aluminum crystals is placed at C, Hull obtains the photograph shown in Fig. 17 (upper). You see the central image, and around it the diffraction rings. It was this crystal diffraction that first gave convincing evidence that X-rays, like light, consist of waves.

G. P. Thomson has performed a precisely similar experiment with electrons. The X-ray beam in the last slide was replaced by a beam of cathode electrons, and gold leaf took the place of the aluminum. The resulting photograph is shown in Fig. 17 (lower). Though it is not quite as sharp as the photograph taken with the X-rays, we can see distinctly the central image, and several

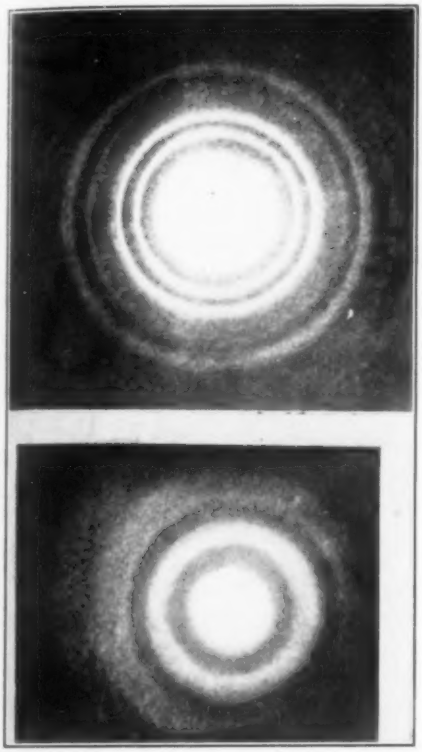


FIG. 17. THE DIFFRACTION PATTERN (UPPER) PRODUCED WHEN A BEAM OF X-RAYS TRAVERSES A MASS OF ALUMINUM CRYSTALS (HULL). (LOWER) PRODUCED WHEN A BEAM OF ELECTRONS TRAVERSES A MASS OF GOLD CRYSTALS (G. P. THOMSON).

rings of diffracted electrons. If the last slide demonstrated the wave character of X-rays, does not this slide prove equally definitely the wave character of electrons?

Most of you are aware of the fact that J. J. Thomson, the famous old Cavendish professor of physics at Cambridge, was largely responsible for proving that cathode rays are electrified particles. About a year ago my wife and I were paying Sir Joseph and Lady Thomson a Sunday afternoon call, and found their son, G. P. Thomson, home from Aberdeen for a week-end. He had with him this photograph, Fig. 17 (lower) showing the diffraction of cathode rays by crystals of gold. It was a really dramatic occasion to see the great old man of science, who had spent his best years showing that electrons are particles, full of enthusiasm over his son's achievement of finding such convincing evidence that moving electrons are waves.

We are thus faced with the fact that the fundamental things in nature, matter and radiation, present to us a dual aspect. In certain ways they act like particles, in others like waves. The experiments tell us that we must seize both horns of the dilemma.

A Suggested Solution

During the last year or two there has gradually developed a solution of this puzzle, which though at first rather difficult to grasp, seems to be free from logical contradictions and essentially capable of describing the phenomena which our experiments reveal. A mere mention of some of the names connected with this development will suggest something of the complexities through which the theory has gradually gone. There are Duane, Slater and Swann in this country, de Broglie in France, Heisenberg and Schrödinger in Germany, Bohr in Denmark, Dirac in England, among others, who have contributed to the growth of this explanation.

The point of departure of this theory is the mathematical proof that the dynamics of a particle may be expressed in terms of the propagation of a group of waves. That is, the particle may be replaced by a wave train—the two, so far as their motion is concerned, may be made mathematically equivalent. The motion of a particle such as an electron or a photon in a straight line is represented by a plane wave. The wavelength is determined by the momentum of the particle, and the length of the train by the precision with which the momentum is known. In the case of

the photon, this wave may be taken as the ordinary electromagnetic wave. The wave corresponding to the moving electron has received no generally accepted name, other than the Greek letters Ψ $\bar{\Psi}$. Perhaps we may call it, however, by the name of its inventor, a de Broglie wave.

Consider, for example, the deflection of a photon by an electron on this basis, that is, the scattering of an X-ray. The incident photon is represented by a train of plane electromagnetic waves. The recoiling electron is likewise represented by a train of plane de Broglie waves propagated in the direction of recoil. These electron waves form a kind of grating by which the incident electromagnetic waves are diffracted. The diffracted waves represent in turn the deflected photon. They are increased in wave-length by the diffraction because the grating is receding, resulting in a Doppler effect.

In this solution of the problem we note that before we could determine the direction in which the X-ray was to be deflected, it was necessary to know the direction of recoil of the electron. In this respect the solution is indeterminate; but its indeterminateness corresponds to an indeterminateness in the experiment itself. There is no way of performing the experiment so as to make the electron recoil in a definite direction as a result of an encounter with a photon. It is a beauty of the theory that it is determinate only where the experiment itself is determinate, and leaves arbitrary those parameters which the experiment is incapable of defining.

It is not usually possible to describe the motion of either a beam of light or a beam of electrons without introducing both the concepts of particles and waves. There are certain localized regions in which at a certain moment energy exists, and this may be taken as a definition of what we mean by a particle. But in predicting where these localized positions are to be at a later instant, a consideration of the propagation of the corresponding waves is usually our most satisfactory mode of attack.

Attention should be called to the fact that the electromagnetic waves and the de Broglie waves are according to this theory waves of probability. Consider as an example the diffraction pattern of a beam of light or of electrons, reflected from a ruled grating, and falling on a photographic plate. In the intense portion of the diffraction pattern there is a high probability that a grain of the photographic plate will be affected. In corpuscular language, there is a high probability that a photon or electron, as the case may be, will strike this portion of the plate. Where the diffraction pattern is of zero intensity, the probability of a particle striking is zero, and the plate is unaffected. Thus there is a high probability that a photon will be present where the "intensity" of an electromagnetic wave is great, and a lesser probability where this "intensity" is smaller.

It is a corollary that the energy of the radiation lies in the photons, and not in the waves. For we mean by energy the ability to do work, and we find that when radiation does anything it acts in particles.

In this connection it may be noted that this wave-mechanics theory does not enable us to locate a photon or an electron definitely except at the instant at which it does something. When it activates a grain on a photographic plate, or ionizes an atom which may be observed in a cloud expansion chamber, we can say that the particle was at that point at the instant of the event. But in between such events the particle can not be definitely located. Some positions are more probable than others, in proportion as the corresponding wave is more intense in these positions. But there is no definite position that can be assigned to the particle in

between its actions on other particles. Thus it becomes meaningless to attempt to assign any definite path to a particle. It is like assigning a definite path to a ray of light: the more sharply we try to define it by narrow slits, the more widely the ray is spread by diffraction.

It is only to satisfy our sense of continuity that we assume that an electron or a photon has a real existence between the occasions at which it acts on other particles. It would be equally permissible to suppose that light or cathode rays alternate in form between particles and waves. While moving from one place to another they would spread out as waves, but when producing any physical effect they would materialize into discrete particles.

Perhaps enough has been said to show that by grasping both horns we have found it possible to overcome the dilemma. Though no simple picture has been invented affording a mechanical model of a light ray, by combining the notions of waves and particles a logically consistent theory has been devised which seems essentially capable of accounting for the properties of light as we know them.

Radio rays, heat rays, visible and ultra-violet light, X-rays, gamma rays and cosmic rays, all are thus different varieties of light. We find from our experiments on diffraction and interference that light consists of waves. The photoelectric effect and the scattering of X-rays give equally convincing reasons for believing that light consists of particles. For centuries it has been supposed that the two conceptions are contradictory. Goaded on, however, by obstinate experiments, we seem to have found a way out. We continue to think of light propagated as electromagnetic waves; but whenever the light does something, it does it as photons. In reply to our question, what is light, the answer seems to come, waves and particles, light is both.

THE SIBUTU ISLANDS

By Professor ALBERT W. HERRE

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TWENTY-ONE miles southwest from the rest of the Sulu Archipelago, and therefore forming the southernmost extension of the Philippines, lies the small Sibutu group. Geographically and ethnologically, it belongs to Borneo.

The Sibutu group includes the following inhabited islands: Sibutu, Tumindao, Sitankai, Omapui, Sipankot and Bulubulu. It also comprises a number of small uninhabited islands and many reefs and shoals exposed at low tide. At the north is the deep mediterranean known as the Sulu Sea, and on the south is the still deeper Celebes Sea. Connecting these two is the broad Sibutu Passage, separating these islands from the rest of the Philippines.

This passage has a depth of from about 100 to 685 fathoms, and is remarkable for the powerful current, locally feared and notorious. In the Samal language this current is known as the "House." During the season of the southwest monsoon the House flows continuously from the Sulu Sea into the Sea of Celebes, with a velocity of five to ten nautical miles an hour. For two or three months, when the current is at its maximum, it is unsafe or even impossible for small launches or the native sailing craft to cross the House. When caught in this current, small boats are often carried southward and landed on the coast of North Celebes or in Dutch Borneo.

Running through the Sibutu group are several deep channels of varying widths, the widest perhaps two miles in breadth, none of them over 150 fathoms in depth. A current similar to the House flows through each of them, but in none of them does it attain a notable or dangerous velocity.

During the period of the northeast monsoon the currents are reversed in all these passages, and flow continuously from the Sea of Celebes into the Sulu Sea. The north-bound currents never attain high velocity, averaging three or four knots an hour, and they have no distinctive name. It gives one a queer sensation to observe these currents moving onward continuously, never slacking, never hurrying, unchanged by the ebb and flow of the tides, day and night and week after week, as though some great river were moving on steadily and majestically. Due to the influence of these currents the fish fauna of the Sulu Archipelago is essentially identical with that of Celebes and the Moluccas.

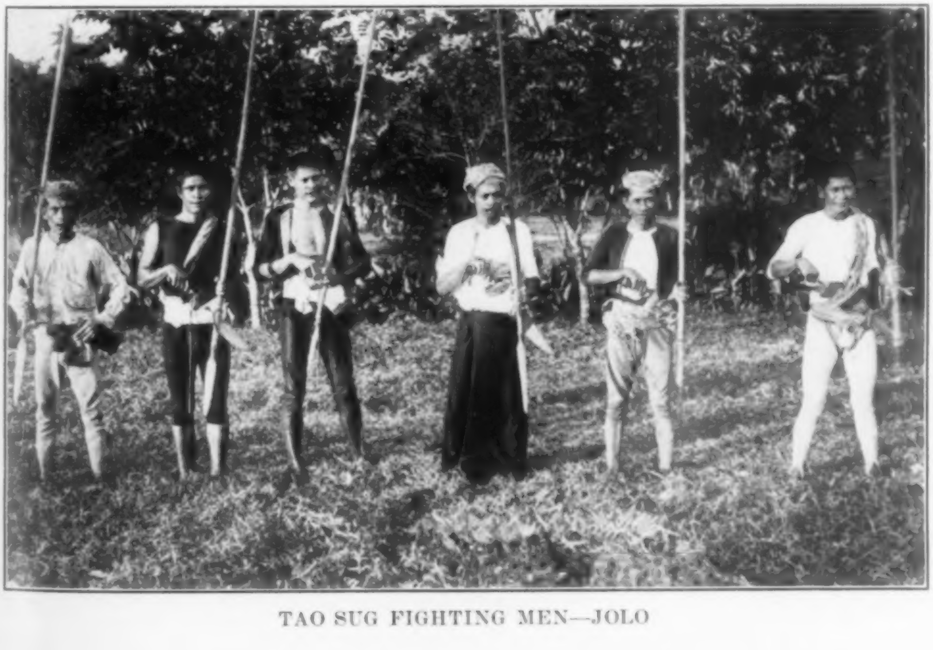
The Sibutu group is composed of low flat islands, which with but one exception do not rise much above high tide. Such islands, due to their uniformity of structure and topography, offer little variety of animal and plant life, but to the marine biologist they are of intense interest, while the people dwelling upon or about them are very little known and would repay careful study. The Sibutu group has long been known as a fishing ground of the first importance in the Philippines and offers an excellent opportunity for the development of commercial fisheries along modern lines.

The largest island is Sibutu, with a length of eighteen and one half miles, and an average breadth of about two and a fourth miles. On the eastern coast of Sibutu, eight or more miles south of its northern tip, is a hill five hundred feet high. It is locally known as the "Mountain," and forms a landmark visible for a great distance at sea, and is an important recognition mark for navigators. This hill is apparently of volcanic origin

DATU MAMA—A TAU SUG NOBLEMAN WITH TEN OF HIS FOURTEEN WIVES

and great blocks of granite are plentifully strewn over its slopes.

All the rest of the island is merely a vast coral reef in many places, if not indeed most, but little changed since it lay beneath the sea ages ago. Around the northern end of the island and along its western shore for many miles, except where the village of Sibutu is located, the shore line is elevated abruptly from



TAO SUG FIGHTING MEN—JOLO

A SAMAL VILLAGE—SULU ARCHIPELAGO

four to eight feet above high-tide level. The base of this elevated portion is, of course, usually more or less undercut by wave action, so that in many places this slight elevation is very difficult to surmount by one approaching from the sea. Elsewhere the shore line is a more or less gently sloping sandy beach of moderate width.

A mile or so north of the village of Sibutu the land back of the beach is raised fifteen or twenty feet above the general level of the island. This elevated portion extends back toward the interior for a half mile or so and runs northward several miles. It was evidently the first portion of the reef to be raised out of the sea and is therefore the oldest part of the island.

Surrounding the island is a reef of dead and living coral which is more or less bare at low tide but is everywhere completely submerged at high tide. This reef varies from a few dozen yards to nearly a mile in breadth and rises everywhere from deep water except at the southern tip of Sibutu. Here the reef forms a southward extension of slight depth until it emerges again as Saluag island, the southernmost extremity of the Philippines.

On the southeast coast of Sibutu the reef forms a lagoon; at its south end this lagoon is very narrow and only deep enough for bancas, lipas and other flat-bottomed native craft. It gradually widens northward, till at the village of Tandu Banak it attains its maximum breadth. Opposite Tandu Banak there is an opening in the outer shore line of the lagoon where launches and other keel-built boats drawing five or six feet of water can find entrance and proceed southward in the lagoon for several miles. On the other side of the island, beginning near the southern end of the village of Sibutu, the reef widens out and forms a sort of very shallow lagoon, mostly bare at low tide, which has a maximum breadth of half a mile. It is very evident that the island of Sibutu has been formed by three successive elevations of the coral reef, the portion last raised being partly above and partly below the level of low tide.

Sibutu is everywhere covered with a more or less dense growth of shrubbery and forest trees, except at the site of present or past villages. Owing to the comparatively xerophytic conditions, there are few creepers or lianas of any size, so that it is not difficult to penetrate the jungle in most places. Few of the trees are of even medium size, though there are some moderately large worthless trees of the genus *Ficus*. Nearly all the trees of any size were cut during the past twenty years to make railroad ties for use in Luzon and the Visayas.

Any one landing at a village on the island and going no farther in than the houses along the shore might well believe Sibutu to have deep fertile soil, ready for the plow when cleared. A trip across the island, or even a few hundred yards back into the jungle, tells a very different story. One walks continuously on coral, most of it apparently unchanged since it was first elevated from the depths of the sea. The surface is very rough and uneven and has more or less soil present in its holes and depressions, but nowhere can one find a continuous layer of soil after leaving the shore line three hundred yards or so behind.

Scattered over the rock everywhere, or embedded in its upper portion, are fossil mollusks in great variety. They are all of the same species that one finds a short distance away in the sea. Most conspicuous of them are the ponderous shells of the great *Tridacnas* or giant clams.

About a mile behind the village of Sibutu, and running northward for several miles, is a broad strip of territory which is of an extraordinary character.

A GROUP OF SAMAL FISHERMEN, TAWI TAWI, SULU ARCHIPELAGO

THESE MEN WILL SAIL 150 TO 175 MILES ACROSS THE OPEN SULU SEA WITHOUT CHART OR COMPASS AND BRING UP AT THEIR DESTINATION WITH ABSOLUTE CERTAINTY.

SAMAL FISHERMEN

GETTING READY TO SAIL ACROSS THE SULU SEA TO PALAWAN OVER 150 MILES OF OPEN WATER.

It is truly remarkable for the incredible number of large, more or less circular, holes contained in this part of the old coral reef. Holes, just plain holes! There they are by the tens of thousands, of all sizes and depths, so closely set together that the ancient reef is riddled like a sieve.

Holes! One sees nothing else! Unbelievable numbers of holes, the ancient fossil reef so thickly spattered with them that for miles hardly a square yard of entire surface can be found. Some are just the right size and depth to take in a man's foot and leg up to the knee, and woe be to the person who should slip into one while walking rapidly, for it would be only too easy to injure his knee joint irreparably. Other holes are of all possible sizes up to enormous pits twenty feet deep and at least five feet in diameter, their sides great vertical stone walls impossible to scale. A man in the bottom of one of those cylindrical well-like holes would be absolutely helpless. In the daytime one must pick and choose his path with great care, while travel at night is entirely out of the question as it is impossible to go ten feet in any direction without landing in a hole. In many places the trail is not over a foot wide, with a yawning hole on either side, while the path winds like a writhing serpent. A slide into any one of those innumerable pits would mean a miserable death, especially if one were wedged head first in a hole just large

enough to fit a man snugly. Yet this could very easily happen if a person stumbled. This whole region is one of weird spookiness, and constant vigilance is necessary to prevent a distressing accident.

About half a mile northwest of the Mountain, not southwest as indicated on the maps, is a permanent pool of water known locally as the "Lake." It occupies a chasm in the ancient reef and is perhaps forty to fifty feet wide. The surface of the water is about twenty-five feet below the level of the surrounding land, and at one place it is possible to descend almost to the level of the water, which is about thirty-five feet deep. On two sides of the chasm the walls of the pool are cavernous, and the water extends back into the cave thus formed nearly as far as the breadth of the open pool. It reminds one of the water holes of Yucatan, though of course it is very shallow compared to them. At one end a huge *Ficus* adds to the picturesqueness of the pool by its vast and intricately branching intertangled mass of roots clambering over the sides and trailing in the water.

At the southern base of the Mountain is a swale and in and around it is the only body of real soil on the island; here several acres of deep black loam occur.

Wild hogs are abundant on the island and, as elsewhere throughout the Philippines, are a constant menace to agriculture. Monkeys are plentiful, and at low tide family groups throng over the exposed reef, picking up crabs, limpets, clams and other sea delicacies. There are no other native mammals larger than rats, except the great fruit bats, which may have a spread of wing of three to five feet, and are very destructive to young coconuts. That most interesting bird, the tabang or brush turkey, a large Megapode, is abundant everywhere. These curious birds lay their eggs in a great mound of decaying vegetation and leave them there to hatch. Several birds lay their eggs in one heap.

The Sulu Archipelago is inhabited by four groups of people, each with its own language. The use of the term Moro to mean a group of natives of the Philippines or their language is highly incorrect. Moro is merely the Spanish name

SAMAL VINTAS OR SAILING BOATS IN THE SULU SEA

A SAMAL VINTA AT JOLO

THE SAMALS LOVE TO DECORATE THE SAILS OF THEIR BOATS.

for Mohammedan. There never was such a thing as a Moro tribe or Moro language.

The best known of the people of Sulu, and the most important politically, are the people of Jolo and the adjacent islands, who call themselves Tao Sug, or people of the current. Their language is also Tao Sug. They are farmers by occupation, but are the political leaders and the aristocracy of the Archipelago. Formerly Jolo was the great slave market and center for outfitting pirates. As it was the residence of the Sultan of Sulu, its people early gained social and political dominance over those of the rest of the islands.

A SAMAL VILLAGE OUT IN THE LAGOON

SANITARY, GUARDED BY BROAD REEFS, SUCH A LOCATION WAS IDEAL IN THE OLD DAYS WHEN PIRACY WAS THE OCCUPATION OF ALL TAWI TAWI.

From Siasi southward to Sibutu Passage live the Samals, speaking the Samal tongue. They are also around the coast of Basilan and in Mindanao on the coasts of Zamboanga and Davao provinces. They dwell in greatest number on the small islands clustered about Tawi Tawi and are the boldest and hardiest fishermen and sailors of all the people of the Philippines. Until driven from the seas by the advent of steam gunboats they were noted for their piratical exploits, ravaging the East Indies from the north coast of Luzon to Singapore and Malacca.

The people of the Sibutu group are ordinarily but incorrectly classed with the Samals. They resent this, however, and call themselves Sibutus; their speech is close to Samal, but it a distinct tongue. The Sibutus are identical with the people who inhabit the coast of Borneo around Darvel Bay and northward toward Sandakan. Their language, customs and traditions are the same, and families are divided, part living on the Bornean coast and part among the Sibutu islands. The people are always visiting relatives back and forth on both sides of the artificial boundary line. The Sibutu people are not such fishermen or sea rovers as the Samals.

Each family grows cassava and catches fish for its own consumption. Little or no effort is made to obtain a surplus, since in most cases it could not be sold. The diet of these islanders is very restricted as a rule, as almost no vegetables are produced and very little fruit grown. However, their diet in the past must have been much more restricted, since cassava has not been known to them more than two hundred and fifty years at the most, having been introduced into the Philippines by the Spanish.

A SAMAL CEMETERY AT SIMUNOL, SULU ARCHIPELAGO

The Tao Sug, Samal and Sibutu people are all Mohammedans, and therefore do not eat the meat of the wild pigs that are so plentiful. All these people have grown a few coconuts from time immemorial, in order to furnish them with cooking fat. During the past six

A LIPA FROM SIBUTU

THE SAIL IS SHIFTED TO ANY ANGLE ACCORDING TO THE DIRECTION OF THE WIND.

years, under the guidance of Governor Carl M. Moore, coconut planting has been systematically undertaken upon a comparatively large scale. It will be but a matter of a few more years till all the available land will be in bearing groves of coconuts, and the islanders will all be relatively rich.

In every village a few chickens, goats and half-starved runty cattle are to be seen, but they are never of importance and are rarely eaten.

The village of Sibutu is composed of a straggling line of houses extending along the water front for more than a mile. Owing to the great waves that sweep over the reef during storms the houses are built, with few exceptions, twenty to fifty feet back of the water line. Like the Samals, the Sibutus build over the water wherever it is possible. Few nipa and bamboo houses of the ordinary Christian Filipino type of dwelling are built. Instead the walls are made of hewn boards, a type of house common among the Samals also. Each house is occupied by a number of people; the smallest and poorest shack has two or three couples with their children, while the larger houses may have several dozen inhabitants.

Around and behind the houses are groves of tall old coconut palms, most of them planted without any system. Among the trees behind the houses and huddled into groups, but nevertheless forming an almost continuous broad row, are the village graves. When a

person dies the body is laid in a coffin, which is placed in a very shallow grave. Around the grave rocks or slabs of stone or thick boards of very hard wood are placed and the space within them filled with white beach sand, which may be heaped up till it is several feet deep. The enclosing wooden or stone slabs are often intricately carved in flowing arabesques or have inscriptions written in Arabic characters. Over each grave is placed a more or less elaborately carved and decorated gravestone or wooden column or board. This grave marker is really a conventionalized phallic symbol and indicates the sex of the buried person.

Drinking water is obtained by sinking shallow open wells here and there among the graves, water being found at a depth of fifteen to twenty feet. It is never very plentiful, and in time of prolonged drought is more or less brackish. On some islands the water is so salty as to be undrinkable except by those habituated to it from infancy, and several of the inhabited islands have no drinking water at all unless rain water is caught.

The Sibutu people, like the Samals, are a Malay blend of many of the tribal types found from the Malay Peninsula to Celebes and Jolo, but they are not so conglomerate as the Samals, who had

GOVERNOR CARL MOORE, DATU JAPAAL, AND VILLAGE ELDER

SEATED ON THE GRAVE OF MAKDUM AT TANDU BANAK, SIBUTU. MAKDUM WAS THE FIRST MOHAMMEDAN MISSIONARY TO REACH THE PHILIPPINES.

A GROUP OF BAJAUS AT SITANKAI, SIBUTU ISLANDS
NOTE THE CAUCASIAN FEATURES OF SOME OF THE MEN.

women of every race, white, brown, yellow and black, in their harems. As among all the Filipino people, there is an admixture of Chinese. Datu Japaal, the hereditary ruler of the Sibutus, resembles in everything but color a plump, heavy-set, prosperous Chinese merchant or official. On inquiry I learned that his maternal grandfather was a Chinese merchant on the coast of Borneo, who had married the daughter of the local datu. Japaal himself was born in Borneo while his mother was visiting her relatives there.

Polygamy is not rare, but as a rule most men can not afford to support two wives. Slavery was always mild and is now almost extinct.

According to local tradition, the first Mohammedan missionaries to reach the Philippines landed on Sibutu. They are always spoken of as Arabs, but it is more probable that they were half-breed Arab traders from Johore. The legend states that there were seven brothers, and that the oldest one, named Makdum, remained upon Sibutu, preaching and proselyting, and that he died there. At the barrio of Tandu Banak, already mentioned, there is a grave covered by a very large heap of white sand. The old men of the village insist that this is the grave of Makdum. It is evidently the grave of a man, for buried far down in the sand we found a broken male phallic stone emblem. Personally, I have no doubt that it is just what the villagers say, the place where Makdum was buried five hundred years ago.

In the southern part of the village of Sibutu, just above high-tide mark, is an old stone cotta or fort, evidently built a very long time ago and now in a ruinous condition. On one corner next the sea is a gigantic banyan tree, the only one on the island and the largest in the Philippines. With its many trunks and innumerable aerial roots sprawled all over the old coral walls of the fort, it was evidently planted generations ago. The people believe that the Kukuk, or spirit of the banyan tree, lures away children.

Formerly the Sibutus paid great heed to witch doctors, but nowadays they will have nothing to do with them. About

1890 there was a great epidemic of cholera and Mahilan, an old woman with a reputation as a jinn or witch doctor, pretended to be able to exorcise the disease. With some of her followers she went to the mosque and held prayers. Then her deluded disciples carried her about the village so that she could repeat her incantations and charms at the houses of all the afflicted. While engaged in this awe-inspiring and laudable task she herself was taken sick and died of cholera before she could complete the tour of the village. This cured the people of their faith in jinn doctors.

Life in a village like Sibutu flows on evenly without rush or worry and demonstrates that much of our alleged progress and complex civilization is either unnecessary or else leads nowhere. There are no factories or stores, hotels or restaurants, streets or roads, newspapers or movies, telephones or radio, police or clergy, bridge parties or country clubs, lawyers or prostitutes or any of the other concomitants of modern city life, some of which are necessary to any considerable group of people, but others are certainly not. There is no booze problem, for the Koran forbids alcoholics and Mohammedans apparently live more closely after their religious precepts than do Christians.

At rare intervals a few tourists may pass. To them such villages and islands seem full of glamor, the home of romance and beauty, full of the lure of the unknown. The half-naked villagers, decorated rather than clothed in the brilliantly colored and lavishly gaudy garments dear to the Mohammedan Malay, add to the attraction and mystery.

The casual visitor, surrounded by the luxury of a steamer, gazes at the half-concealed nipa-bamboo cottages ashore and sighs for an idyllic life in a palm-embowered love-nest. Lost in a maze of mush and sentimentalism, tamely married army wives, plump and long past the bloom of youth, or well-endowed old-maid school teachers yearning for life, indulge in vague dreams of love with a thrilling and satisfying soul companion who carries them away from the prosaic world to dwell beneath the dense canopy of a coconut grove beside the jewel-like beauty of a coral reef. There the perfume of waxy-white frangipanni and seductively glowing orchids, the enchanting song of great golden orioles

A BAJAU HOUSE AT SITANKAI, SIBUTU ISLANDS

A BAJAU VILLAGE OF HOUSE-BOATS
TUMINDAO, SIBUTU ISLANDS.

and voluptuous cooing of huge flower-like fruit pigeons would lull their senses, while they fed on the honey-dew of kisses and love.

As a matter of fact these dreamers, deprived of ice and a rich varied diet, cut off from bridge and teas, could not stand existence on one of those lone coral isles. Only the naturalist or one rich in inner resources and therefore not afraid to be alone with himself can enjoy an extended stay in such places. Even among such choice spirits it is only a few who can overlook the frequently monotonous diet and insufficient water supply, and who can successfully resist intestinal infections and parasites; none but these can really enjoy a prolonged

SITANKAI, SIBUTU ISLANDS
THE SOUTHERNMOST TOWN OF THE PHILIPPINES.

stay on these "isles of the coral-studded sea."

There is a school at Sibutu, with Christian Filipino teachers, where Mohammedan boys and girls are taught things as unreal to them and as disassociated from their present and future lives as a knowledge of non-Euclidean geometry is to a garbage collector. I do not mean to say that these children should not go to school, but I do say that the present curriculum is not one adapted to their needs. In general it trains them away from the life about them without substituting anything valuable to replace what they have lost. They can not all be teachers and apparently that is all their schooling fits them to be.

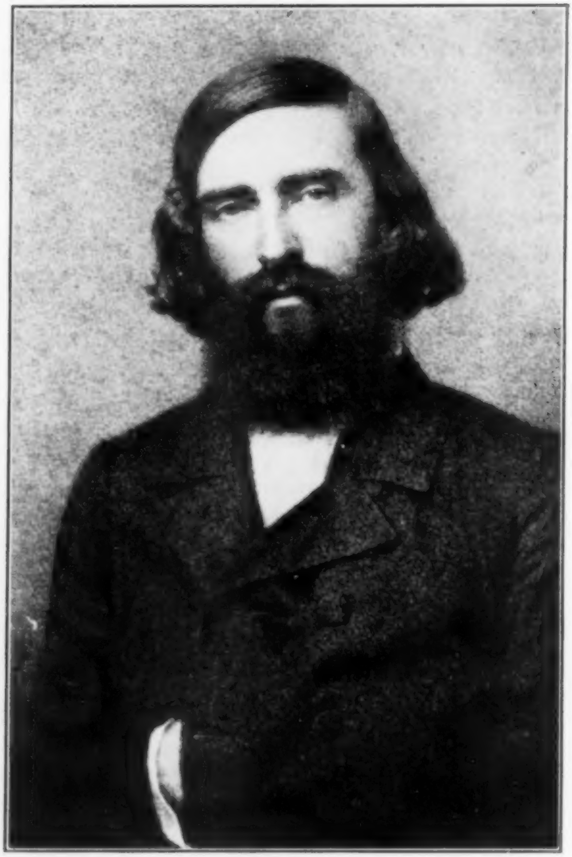
The Sibutu Islands are the Philippine headquarters of those strange sea-dwellers known as Bajaus by the Samals and called Sitankai in the Sibutu language. They are widely known as sea gypsies and are true nomads of the sea. The Bajaus are a comparatively tall lean Indonesian pagan people. They are found only along the coasts of Borneo, Celebes and the Sibutu Islands, although a few venture now and then as far north as the Tawi Tawi group. They never live on land but are born, live and die on the sea, making their homes in rude houseboats. These are moored in clusters or groups which might be termed villages, hidden in some sheltered nook and protected from storms and waves. In addition to their houseboats, the Bajaus have lipas or bancas which they use for fishing or going about while engaged in their everyday affairs. The Bajaus live exclusively by fishing and are very skilful when one considers the crude methods and appliances at their command.

The Mongol strains in the Malay race seem to be little evident in the Bajaus, and the Indonesian element seems to be stronger than in any other inhabitants of the Philippines. Many of them are European in appearance except in color, with regular Caucasian features, and are tall and well built. Unlike the Mohammedans and Christians, both men and women wear the hair long. Little is known of their language or customs. Unlike their land-dwelling neighbors, they apparently have no domestic arts such as weaving and pottery making. Their food is almost exclusively fish and cassava, the last purchased from their land-dwelling neighbors.

Rumor blackens their religion, morals and social organization. Incest is said to be very common. Such reports must be largely discounted, but it is evident that they have no very elevated standards. When people are huddled together permanently into very confined quarters, things are prone to happen which would be very unlikely to occur under different living conditions

Each little group of Bajaus seems to be largely independent of all others. The Bajaus are a feeble and comparatively timid people, in former days defenseless against their piratical neighbors and unable to develop any numerical strength because of their mode of living. They have been able to survive as a definite tribe because of their extreme poverty, which offered nothing to the Samal pirates. Then, too, their habit of hiding in small groups along the shores of sequestered bays on uninhabited islands, often where strong currents made navigation difficult for sailboats during much of the year, has been an important factor in their maintenance.

The only land with which the Bajaus have any permanent relation is a tiny island which the Sibutu people long ago named after them. From time immemorial it has been their burial ground, and accordingly the Sibutus named it Sitankai, which is what they call the Bajaus. On this minute island, which is only about ten hectares in area, is the town of Sitankai, which has the distinction of being the southernmost town in the Philippines. It is of much importance for its commercial fisheries.



ALBRECHT VON GRAEFE (1828–70)

ALBRECHT VON GRAEFE

THE FOUNDER OF MODERN OPHTHALMOLOGY (1828–1870)

By Dr. THEODORE KOPPÁNYI
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One of the greatest of the great scientists and benefactors of suffering humanity was Albrecht von Graefe, a man of whom his native country can justly be proud. But science is international and his work is a blessing to all mankind. Nowhere should the one hundredth anniversary of his birth pass unnoticed.

Albrecht von Graefe was the distinguished son of a distinguished father. Karl Ferdinand von Graefe (1787–1840) was professor of surgery at the University of Berlin and eminently successful in the practice of general and ophthalmic surgery. His name is inseparably associated with the revival of plastic surgery, especially rhinoplasty, *i.e.*, an operation for forming a nose from the skin of the forehead. He died rather suddenly at Hanover, whither he had been called to operate on the crown prince.

Albrecht von Graefe (born May 22, 1828, at Berlin) received at home a good early training. His father's death did not interfere with his education, and under the guidance of his high-spirited mother he spent a happy childhood in their beautiful home in the Berlin "Tiergarten." Maturing early, he graduated at the age of fifteen from the French gymnasium in Berlin.

Believers in the heredity of intellectual faculties could point to the von Graefes as one of the numerous examples where illustrious fathers did not have mediocre or obscure children. And protagonists of the theory (so ably criticized by Professor Jennings) that the relatively advanced age of the father has a beneficial influence upon the general ability of the offspring could emphasize the fact that Karl Ferdinand von Graefe was forty years old when his son was born.

Even in the secondary school, young Albrecht showed preference for mathematics and natural sciences, and these disciplines did not cease to attract him while a student or graduate in medicine.

One of the youngest students ever entering a medical school, von Graefe studied at Berlin under such men as Johannes Muller and Rudolf Virchow. At the age of twenty he received his M.D. degree. The financial independence of his family was very advantageous for the young physician, for he was able to set out for a long journey, his scientific "Wanderjahre." In Prague he first came into contact with ophthalmology as an independent discipline, represented there by Professor Arlt. This great teacher was largely responsible for the fact that von Graefe chose ophthalmology as his main field of interest. From Prague he went to Paris and associated himself with many excellent eye specialists, and, above all, with the greatest experimental physiologist of France, Claude Bernard. In Vienna, "the birthplace of ophthalmology," he worked with the two Jaegers, father and son. Again it was his good fortune that his Viennese sojourn occurred during the "golden age" of the medical school of that university. London was the next and last stop in his itinerary, where he studied with Bowman and Critchett.

Upon his return to Berlin, von Graefe founded an eye clinic, a model institution at that time. His alma mater offered him an associate professorship in 1856 and he had to wait ten years before he was made full professor and director of an independent university institute for ophthalmology. In the meanwhile, supported by his old teacher and friend Arlt and the Hollander Donders, he started a periodical in ophthalmology, which is still the leading German publication in that branch.

Von Graefe was a man of delicate health and suffered much and heroically from tuberculosis of the lungs. Fortunately, he was unusually happy in his family life and the self-sacrifice of his beloved "little bride," the Countess Anna Knuth, greatly increased his working capacity. But when his wife developed pneumonia and became an invalid for the rest of her life and two of their children died, his own condition rapidly grew worse, and only four years after his appointment as full professor he was cut off prematurely by death (August 20, 1870, at Berlin). He continued to work until almost the day of his death. He had to use morphine to enable him to lecture and to operate. On the night of August 19 his condition became critical; he felt that the end was approaching. He wanted to see the daybreak. Like Goethe, he wanted "Licht, mehr Licht." On the next morning he fell asleep in his armchair and did not waken.

Von Graefe was a man of strong liberal and democratic tendencies and a humanitarian in the truest sense of the word. Wherever he went people flocked to him, and even during his summer vacations he was always ready to help the sick, be he rich or poor.

The contributions of Albrecht von Graefe to ophthalmology are so numerous and some of them so technical that we can hardly do more than mention some of his epoch-making innovations. The eye-mirror, or ophthalmoscope, an instrument invented by the great physicist, Helmholtz, in 1851, made the interior of the eye accessible to investigation. It is based on the principle that a beam of light reflected from a mirror is thrown into the eye through the pupil and upon the fundus of the eye, and a reflection of this light is received through a hole in the mirror into the observer's eye; and thus one obtains an image of the fundus of the eye examined. Von Graefe recognized at once the importance of this discovery in the diagnosis of the diseases of the eye. In von Graefe and his friend Donders' hands, the eye-mirror soon became the instrument which disclosed to us the abnormal changes of the inner eye membranes and their blood vessels and nerves. It enabled the medical profession to study these processes, recognize their early appearance, and thus make early and rational treatment possible. It was found subsequently that not only diseases of the eye, but involvements of the nervous system and other organs also produce changes in the eye ground and the eye-mirror was extended to other fields in its application. In this field, too, von Graefe made a fundamental discovery. He observed that one of the early symptoms of increased intracranial pressure was a change in the characteristic appearance of the optic cup. This is very important in the early recognition of the existence of brain tumor. The eye-mirror thus became indispensable in the fight to combat disease, and it was chiefly through von Graefe that it created a revolution in ophthalmology, and that it has, in more than one sense, thrown light into regions that were formerly completely dark.

If the crystalline lens becomes opaque, seeing images is no longer possible. Several surgeons succeeded in removing the opaque lens from the eye

and restored vision. But the hazards of this operation were great, and very often eyes were lost, due to the suppuration of the transparent outer coat of the eye, the cornea. Von Graefe thought that this suppuration was due to the great gaping of the incision, and that the lips of the wound were not properly applied to one another. He developed a new and better technique, which made the removal of the lens *a safe operation*. About the same time Lister made his famous discovery of germs as the cause of post-operative suppurations and infections. Von Graefe saw Lister personally, was deeply impressed by the British discovery and adapted the antiseptic procedure to operations on the eye. Thus he taught his colleagues how to be doubly sure to avoid infection following the removal of the lens and in other eye operations. He also advanced operative technique by inventing a number of surgical instruments, especially his famous linear knife, which are as widely used to-day as shortly after von Graefe's introducing them.

Von Graefe introduced silver nitrate for the treatment of suppurative conjunctivitis, a treatment eminently effective to this day. His interesting study of the physiology of the eye muscles led him to introduce various surgical methods for correction of squint.

Von Graefe's sign, an important diagnostic symptom, is generally used in physical examination of individuals in whom exophthalmic goiter is suspected. This sign consists of the individual's inability to lower the upper lid when told to look at the floor.

These contributions alone would insure von Graefe's claim to immortality, and yet his fame chiefly rests on another epoch-making discovery. This concerns the discovery of the nature and cure of a terrible eye affliction called *glaucoma*. This disease, which manifests itself by disturbances of vision accompanied by severe pains, resulted inevitably in blindness, and even then the tribulations of the patient did not end, for he was still tortured by pain. Von Graefe made a most profound study of the disease and came to the conclusion that all the symptoms of the glaucoma were due to one single fact, the increase of the pressure within the eyeball. He thought that the remedy must consist of a lowering of the pressure. That he achieved by removing a piece of the iris. The result proved the correctness of von Graefe's assumption. Thousands of people, all over the world, are now saved every year from blindness through von Graefe's iridectomy.

Von Graefe's early training in the fundamental exact sciences was surely one of the chief factors which made his great discoveries possible. It made ophthalmology perhaps the most exact of the medical disciplines.

Von Graefe died young, scarcely at his prime, but his work was finished. He had fought well against the Powers of Darkness.

GOOD HOUSING FOR FAMILIES OF MODEST MEANS

By Dr. JAMES FORD
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PROGRESS is impossible unless each generation is provided with conditions of living superior to those enjoyed by preceding generations. Our chief obligation as citizens is to see to it that our children may have a better start in life than we had.

Man is deeply influenced by his environment. The best of human stock may be injured and its development thwarted by adverse conditions. A farm crop depends not merely upon well-selected seed, but also upon proper conditions of cultivation, soil, climate and weather. Similarly human personality and character are the result of the play of environment upon native individuality.

Our immediate problem is to find out how good housing can be brought within the reach of families of modest means, which constitute the majority of our population. It should be recognized that most families will be compelled to live in old houses. If the average life of a house is from one third to one half of a century, most persons can not live in new dwellings. So our first question is to ask how old houses can be made better.

The obvious answer is that there should be good building laws, health laws and housing laws, wisely framed by citizens who have practical knowledge of the subject of housing and who though cognizant of practical difficulties have standards that are high and sound. Such laws must be enforced by wise and practical citizens whose standards are also high. As no law is self-enforcing, it is necessary to have in each city a body of local citizens to make a continuous survey of housing needs and standards and to lend public officials their moral support and assistance. Philadelphia, New York City, Brooklyn, Pittsburgh and Cincinnati have such organizations, but in most other cities there is no such medium of community service. Standards of housing legislation and enforcement are therefore relatively low.

The next essential is to have agencies for the education of tenants and landlords which can help the latter to see that the ownership of rentable property is a form of trusteeship in the service of the community and can help tenants to recognize their responsibilities and privileges as parents and homemakers and as neighbors and citizens. In this field, again, Philadelphia is peculiarly fortunate in having the Octavia Hill Association, which has done outstanding work through its ownership of old remodeled properties and through its rent-collecting agency. This service to both home owners and tenants should, however, be universally available, since no citizen, whether owner or tenant, can, without help, keep fully informed of the most economical and most effective ways of making improvements in his own property. In rural regions admirable service is being performed through the extension departments of state colleges.

The organization of local volunteer Better Homes in America committees is a valuable supplement to these other forms of service, because such committees are made up of leading local citizens representing the various civic agencies of the community. A great deal of advice and help on local problems is

available through the civic organizations which are represented on the local committee, and virtually the whole population is reached through the lectures, discussions, contests and demonstrations which are arranged. By adapting their programs to meet the most urgent of local needs as they find them, and by varying their programs from year to year as new problems appear or old ones are solved, they contribute greatly to the leveling up of prevailing standards.

By demonstrating to the community the best examples of effective reconditioning or remodeling of old premises they prove that notable improvements can be accomplished at a cost that is relatively low. They can also stimulate the local public to make improvements on their premises through home improvement contests, kitchen contests, living-room contests, home garden contests or neighborhood improvement contests. Contests have appeal both to man's competitive instincts and to home and community pride. Hence notable progress in the bettering of local standards for families of modest means may be made in any given year.

Families that are relatively poor have ordinarily been condemned to live in the cast-off houses of the families next above them in the economic scale. But as all our cities are growing through births and immigration and through migration from less populous districts, new houses have to be built each year to accommodate this increase, as well as to replace dwellings eliminated by obsolescence and by the extension of business and industrial areas. The housing shortage caused by the war has been largely met in most American cities so far as homes for the well-to-do are concerned, for the obvious reason that larger profits for speculative building are possible through catering to these classes first.

The question may properly be raised: would it not be possible to provide good new housing within the reach of wage-earning families? The division of building and housing of the Department of Commerce estimates that under ordinary conditions a wage-earning family can afford to spend for its home a sum equal to from two to two and one half times its annual income. Thus, a family whose members regularly earn $2,000 a year could afford a house which, with its lot, would cost from $4,000 to $5,000; and a family earning $1,500 a year could afford a house which, with its lot, would cost from $3,000 to $4,250.

Can unskilled wage-earners also be reached? In the south this question is already answered in the affirmative, for labor and construction costs are low and cellars and central heating equipment do not have to be provided. The answer is more difficult in the north because of higher land, labor and construction costs, and also because the family that is willing to live in a three-room flat would scorn to live in a three-room house. Yet I am confident that within the coming generation we shall be able to solve this problem, too. There are several points of attack, and some research by specialists will be necessary before an entirely satisfactory solution of universal applicability will be found.

The first essential is to discover the most economical house plans that are consistent with good architectural design, and to make these plans accessible to operative builders and to individual home builders. A square house is ordinarily the most economical as to material, the cheapest to heat and the easiest to furnish; but most plans for square houses are hideous from the point of view of design, and our unfortunate practices in the subdivision of urban land practically preclude this type of house except in the remote outskirts of our cities. The Architects' Small House Service Bureau, established by the American Institute of Architects, pro-

vides plans at low cost for persons who would not ordinarily have access to the services of good architects, and is performing excellent service in this field. It is, however, confining its activities to the detached single-family house. In general, our best architects have not been interested in solving the problem of single-family housing, semi-detached housing or row or group housing for the wage-earning population. There is an immense field for public service here. The problem probably can not be met except through endowment funds, for experimentation is costly and seldom lucrative.

The next essential is judicious experimentation in standardization. A tailor-made suit costs about twice as much as a ready-made suit. Similarly when houses are "custom" made, their unit costs are high. Herbert Hoover, with characteristic vision, has, through the division of simplified practice of the Department of Commerce, succeeded in making standardized units for building materials and equipment generally accessible to the American public at relatively low unit costs.

It is necessary to make standard house plans of economical, efficient and convenient type, universally accessible. With such plans there should be a wide variety of exterior designs, each artistic in character, so that a whole community may be built with the use of not more than a half dozen standard floor plans but with varied exteriors. Thus monotony would be avoided and the economic advantages would be possible which come from buying standard materials by the carload and from using teams of laborers who are familiar with the plan and who can, therefore, build with a minimum loss of time between operations. When whole communities can be built from satisfactory standard plans and standardized materials, the unit cost will be at a minimum for services of architect, contractor, engineer, labor, legal advice, financing, land and utilities. Hence if good new housing is already within the reach of skilled labor, it is a safe presumption that by these means good new housing can be brought within the reach of unskilled wage-earners as well.

There are several other measures which can be applied to reduce the cost of housing. Some of these are immediately applicable, and others would take a generation or more to get established. An example of the latter toward which we should definitely move is industrial decentralization. If factories can be moved out from the hearts of our cities to remote suburbs or the open country, it will be possible to plan and build whole villages of wage-earners' homes, applying the best principles of architecture, city planning and landscape gardening to the project. This program is much more possible of accomplishment now than it was two decades ago, due to the tremendous development of superpower and of power transmission, and should be seriously considered by all far-sighted groups in the field of town planning and housing. For with the necessary power available and with land purchasable at its agricultural value and with the relatively low tax rates of rural districts and the possibilities of spur track connections with railroads, the decentralization of industry becomes a practical possibility. Residential decentralization should accompany it. Of course, such a program would involve a better development of labor exchanges and adequate opportunities for recreation in the new garden cities. But there is sufficient knowledge now at hand to meet all of these needs and to provide cultural opportunities and wholesome indoor and outdoor recreation as well as private, secluded, beautiful homes for all industrial workers. We should be content with nothing but the best. The best

is now practically within reach, and by far-seeing social service the amenities of life can be afforded to the industrial worker and his family.

Other devices for reducing housing costs include measures for city planning and zoning, for cheap and easy money for house building and home acquisition and for cooperative ownership. English experiments with copartnership housing have demonstrated the possibility of providing harmoniously developed communities through garden suburbs for wage-earners, and have shown that cooperative ownership is better than private ownership for industrial workers in certain types of communities, as it gives them freedom of movement and makes the disposal of their properties relatively easy in case they wish to move elsewhere. At the same time there are no losses from arrears in rent in cooperative colonies because the shares of stock can be seized to meet any such delinquencies. There are no losses from vacancies because each shareholder in the cooperative group will wish to bring his friends to the colony, and in the case of a vacancy, they are all, therefore, in a sense renting agents. Moreover, upkeep costs are at a minimum because each tenant has every incentive to keep his own place in repair. Copartnership housing can not be experimented with profitably, however, at this time and will need much more study to adapt it to American conditions.

Town planning can reduce housing costs for residential quarters first by making all of the outskirts of the city accessible through direct radial or arterial traffic routes. If suburban land is accessible in all directions from the city, there will be more owners ready to sell, and the cost of land per lot will be correspondingly low. For it is scarcity of land of any given type that makes land costs relatively high. Broad arterial streets connecting centers and sub-centers also facilitate rapid and cheap transit and thus make it possible for "downtown" workers to live in private residences within a half hour's ride of their place of work. It should be the inalienable right of every free-born American to live in a home of his own within easy access to his place of work, and no man should be condemned to be a straphanger for more than one hour per day. The decentralization of industry should, however, ultimately make possible for every industrial worker a home within walking distance of his place of work.

Town planning can also facilitate improved housing through judicious subdivision of blocks and lots in residential areas. In general, in our American cities lots are too narrow and too deep. Winding streets in protected residential areas may be narrow and relatively inexpensive, ornamented at slight cost with grass strips and trees, and in this way provide attractive vistas for every home.

Zoning in cities makes possible the separation of industrial and business areas from residential areas, and can thus protect homes from the dust, noise, fire-risk and chemical fumes of the factories. The trucking to and from factories can be kept off residential streets, thus reducing accident dangers. Zoning also prevents the beauty of residential streets from being marred by the ugly outline of the factories.

Through zoning it is now possible also to keep apartment houses out of single-family-house neighborhoods, thus reducing the volume of traffic on residential streets and preventing huge multiple dwellings from overshadowing their neighbors. Neighborhood shops can be localized at strategic sub-centers accessible to the residential neighborhood, and thus nothing need mar the charm of the homes of our citizens of modest means.

Cheap money for home building and home acquisition is necessary if home

ownership is to be rendered universally possible. Of the importance of home ownership for most families there can be little question, because it gives all members of the household a common interest of a vital sort, an opportunity for common sacrifice for a worthy end, an opportunity for common self-expression and family pride, and, most important of all, a stake in the community and recognition of the duties and the privileges of citizenship.

The most important agency for coping with this problem is the building and loan association. But some such associations have tended to favor the investor against the borrower by charging relatively high rates of interest for money borrowed for home acquisition or home construction. If borrowers could secure first mortgages at 6 per cent. interest, as they do in the cooperative banks in Massachusetts, and second mortgages at 7 or 8 per cent. without the payment of premiums, home ownership would be encouraged.

Other countries provide government credit for house building, subject to plan supervision by the government, but we have probably rightly assumed in America that that should be looked upon as a last resort and that our problem should and can be met through private agencies. There are some evidences that second mortgage loan companies can be established in this country to lend money on residential property at interest rates as low as 7 per cent. Study of these ventures might lead to a considerable extension of this practice wherever it may prove practicable. Easier terms of amortization of loans may prove necessary for wage-earners, particularly for those who are unskilled. A lengthening of the period of amortization from fifteen to twenty years might bring home ownership within the reach of unskilled workers much more generally than is now the case, and still might be consistent with conservative and safe mortgage investment on the part of the lenders.

Labor costs in small house construction, as has already been pointed out, can be reduced by standardization, which would reduce the loss of time involved in waiting for materials or instructions. Large scale construction also makes possible continuous work for gangs of carpenters, plasterers, plumbers, and others, who can move from house to house on a predetermined route. It is likely that during the next generation experiments in house construction will lead to the common use of new processes of fitting together houses from mill-made parts in each of several different materials, and thus make possible the use in large part of unskilled labor in house construction. A more general use of winter construction, as suggested by the U. S. Department of Commerce, will have the advantage of keeping the building trades active throughout the year and of making it possible to build houses with relatively little use of overtime labor and thus with slight expenditure at overtime rates.

Carrying costs for home owners, once they have moved into their new homes, can be reduced through building homes of sound construction. The jerry-built house may be cheap to acquire, but is costly to carry, as it is continuously getting out of repair. Easy interest and amortization rates have already been mentioned, and the low carrying costs of cooperative ownership have been discussed. One remaining possibility is the reduction of taxation on improvements, or even the removal of taxes on homes. I am not prepared to advocate the latter, in spite of New York's experience with it, but it would be worth while to study this subject carefully. It would also be well to study the experience of Pittsburgh and other cities in progres-

sive reduction of taxation upon improvements to see if it does not indicate an important social policy for the promotion of home building and home ownership.

Where houses are well built and of good design and where community standards of city planning and neighborhood upkeep are high, there will be an actual appreciation of land values, which in turn will increase the borrowing capacity of owners and afford them an opportunity for a substantial profit when they dispose of their homes and move to new quarters. Community values and community reputation are, of course, enhanced by good architecture, good construction and community planning.

PICK-AXE SCIENTISTS

By Dr. WALTER EARL SPAHR
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In a recent address before the Wharton School Alumni Society Mr. John Hays Hammond took occasion to comment very pointedly upon the great, if not startling, advances made in recent years in the fields of the pure sciences, such as physics, chemistry, astronomy and mineralogy, in contrast to the lagging scientific developments in the so-called social science fields. Referring particularly to mining, he pointed out that fifty years ago the prospector did his prospecting with his ever-present pick. To-day the most advanced and refined resources of modern science are utilized; the certainties of scientific methods are substituted for the chance results of the man with his pick; the trained geologist and even the radio serve to reduce chance to a minimum. The social scientists, however, have hardly advanced beyond the pick-axe stage; their methods doubtless are little advanced beyond the methods employed by the exact scientists in medieval times, and by implication, Mr. Hammond dubbed the latter "pick-axe scientists." With his observations it is reasonably certain that competent scientists of both fields agree.

In the fields of exact science, both pure and applied, the modern developments are a source of daily wonder. Starting from small beginnings characterized by endless experiments in what to-day are simple fundamentals, these scientists have worked slowly and painfully throughout the ages. An outstanding discovery in a century would serve as a stepping-stone and guide for the next scientist who, with the impetus of this start, could work more rapidly and more effectively than his predecessors. Each discovery, suggestive in its implications, would beget others. The effect was cumulative until a mere generation would witness an epoch-making discovery, then a decade, then a single year, and now they come so rapidly that we are left bewildered. We no longer attempt to keep abreast of the developments; rather we merely trust the scientist to provide us with anything that fancy might suggest.

The world's confidence in these scientists is evidenced by the huge industrial laboratories established by our leading and foresighted industrialists, by the fact that they sponsor and finance lavishly not alone the applied but the pure scientist, by the fact that they employ the best scientists and let them work without restrictions, by the fact that leading philanthropists do not hesitate

to endow chairs, establish laboratories and build science buildings whenever needed and almost without question. Business men, philanthropists and governments show no hesitation in furthering the cause of the exact sciences; they know the results will more than justify the outlay; they know that the greatest contributions to modern progress have come from these sources. These facts are no longer questioned by those competent to appraise the situation.

With respect to the contributions which the social scientists have made to human progress it is agreed by those well aware of the true status of affairs that their contributions pale into insignificance when compared with the contributions of the exact scientists. It is doubtful if the social sciences are little more than medieval in dealing with political, economic and social problems.

The principles of scientific method as applied in the exact sciences are very simple, although the technique of applying them has long since grown so complex that it is comprehensible only to the highly trained mind. Simple as these fundamental principles are, the social scientists can hardly be said to approach within even a respectable distance of them.

One of the most elementary and cardinal principles of the exact scientist is to gather his evidence through direct observations made while conducting experiments. The evidence upon which the social scientist relies is almost altogether indirect; there is very little, relatively, which he observes directly, since his problems are so widely diffused through both time and space that he must gather up as many observations of others as possible and from such uncertain evidence draw what generalizations he may. From experimentation, as conducted in a laboratory, he is practically excluded. No exact scientist, for a moment, would accept as reliable evidence the very best evidence available to the social scientist.

The exact scientist insists that the observations of experiments be recorded by the observer at once in an exact, precise method, which indicates in detail how the experiments and observations were made and the conclusions deduced. Few indeed are the social scientists who record their observations at once. Instead they rely upon memory, which is fickle, selective and unreliable, and which at the best is based upon their own individual and single observation, and which of course can not yield scientific conclusions. Yet the social scientist usually makes it a point to advertise conclusions based upon his direct observations, often not realizing that it requires many direct observations of several persons working independently to yield scientific conclusions. Aside from his few direct observations most of his evidence is composed of the observations of others, and such evidence no exact scientist could accept and still call himself a scientist.

The exact scientist will not claim that he can draw scientific conclusions so long as competent fellow scientists disagree as to the facts involved, while the social scientist is not at all deterred by what often appear to him to be the pedantic standards set up as the requisites for scientific truth. He relies upon a few indirect sources and occasionally upon a single bit of indirect evidence, failing to observe that at the best his evidence is but a presumption more or less strong, not an established fact.

The exact scientist has as tools exact formulae meaning the same thing to all scientists. The social scientist has few such formulae in his possession and as a result can not present his conclusions in such brief, concise form, and always flirts with inaccuracy and approximation, and is certain to be misunderstood in some respects.

A science to fulfil its functions must enable the scientist not only to classify, analyze and generalize his data but also to forecast. We are quite accustomed to the exact forecasts of the astronomers and of the other exact scientists and recognize quite well that the one thing that the social scientists can not do is forecast. A science is at its best when it enables human beings to forecast events and in this respect the social sciences have failed dismally. Indeed these very shortcomings have caused some thoughtful persons to insist that the social sciences are really not sciences at all. It is also interesting to note the paradoxical fact that could the social scientists really learn to predict, the predictions would defeat themselves in those cases in which the masses would wish to take advantage of the forecasts. Once the populace learned to rely upon a social prediction, social foresight would discount the prediction at once and nullify the prediction. This is the reason why there never can be a genuine barometer of business conditions; as soon as the masses come to believe that such a barometer has been devised it will be defeated at once by the immediate discount of the prediction. It appears, as a result, that forecasting of price levels, etc., is an eternal problem and always doomed to failure in some degree.

The social sciences, it must be observed, are not characterized by truly scientific methods in the most exact sense. Rather the common methods are more or less irrational ones. We settle issues by votes, by out-shouting one another, by political strategy, or, if need be, by force. In no place is the irrationality of our methods of settling important social questions more obvious than in the settling of international disputes through force of arms. The human brain could not conceive of a more irrational thing than war and yet we have developed a series of pseudo-rationalizations to justify it. In the simplest terms it is but a retention of the most barbaric and elemental weapon of the crudest savage. And yet it is one of the chief methods still used by modern society in settling disputes.

In brief the exact sciences and the mechanical forces which surround us have developed so rapidly and so far beyond the social sciences that we are confronted with the very pertinent question as to whether we have not created a mechanism which may crush us. It has been said by that keen observer, Mr. Edward Slosson, that "Man is mounted upon a horse bigger than he can ride. . . . Science has endowed men with the power of supermen but his mind remains human. . . . He is like a pauper with a fortune, a laborer made a boss, a private promoted to command a regiment, a slave made master of slaves. . . . "

Despite the object lesson observable in the astonishing developments of the exact sciences "we still use," to quote Mr. Hammond, "a pop-gun method in the study of economic problems." Our methods are very unscientific, often very irrational, and as a result, poorly supported. If there is to be any solution at all it must come through more and better research in social sciences. Social sciences must receive better support; leading social scientists must be endowed. Governments, business men and philanthropists must aid, else the marvelous superstructure built up by the exact scientists may come crashing down due to the flimsy social mechanism underlying. The late war raised the question in many people's minds. Farseeing people continually dally with the phenomenon; philosophers as well as scientists warn us and yet relatively little is done. Thus far social scientists are fighting a defensive battle; the masses as yet, and certainly the business men, care little what social scientists do or say, so long as the technicians con-

tinue to advance their material welfare as they have been doing.

It would seem that all rational persons with an enlightened self-interest must be concerned with the welfare of the scientists in the social science fields; they must aid them, endow them and encourage rational and scientific methods in the conduct of social affairs whenever and wherever possible. If rationality means anything at all this appears to be the proper means for securing sound advancement in human welfare. Such support, it is to be feared, will come slowly; the general public attitude is against it; the uncertain and intangible do not have the appeal that the more certain and the more tangible developments do. And under the most favorable conditions and with support even more liberal than that given to the exact scientists, real results must come very slowly and haltingly.

A realization of these apparent facts must convince us that those who work in social science fields are working under terrific handicaps when compared with their brothers in the exact sciences. The possibilities for genuine achievement and true distinction are almost infinitely less. Workers in these fields can only express a hope rather than a well-founded belief that they may be among those scientifically minded persons who may accomplish something of real value in this world. They are in fact little more than pop-gun or pick-axe scientists. But the fault is not their own. They are handicapped not only by the methodology they must employ but by lack of sympathetic understanding on the part of others and by lack of adequate financial support. The limits of their methodology can not be changed appreciably, but a better comprehension of the fundamental nature of their work can be cultivated and a far more liberal financial support must be given.

NOTES ON A MODEL LANGUAGE

By Dr. MAX TALMEY

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I. Qualification for the Construction of the Model Language

A language expressive to the greatest possible extent and free from the faults inherent in all natural languages would be beneficial to persons of different mother tongues who, by education and training, are able to communicate to one another ideas of real value. Such a language serving the need and advantage of the substantially educated people of the various nations may be designated as the Model Language (ML) to distinguish it from the International Language (IL) by which is usually understood a language common to the masses of all nations, excellence being subordinate.[1] Elsewhere[2] the writer has pointed out that an IL in this commonly accepted sense is not needed at all. The present essay is not concerned with such an IL, but deals with the ML as defined above.

The ML can only be a constructed system. The answer to the question, who is best qualified for the task of constructing it, follows from the consideration of the views of an eminent scientist regarding language in general. In "Weltsprache und Wissensch." Wilhelm

[1] In modern times Universal Language (UL) has become synonymous with IL, but originally UL meant the same as ML.

[2] "Arulo," p. 43.

Ostwald advances the following statements:

(1) Every language represents a group of signs coordinated with a group of conceptions in such a way that every particular conception has its particular sign.

(2) The system of conceptions is the only thing that matters; for with them one may coordinate arbitrary signs, and the value of the resulting language remains the same irrespective of the signs selected. The accidental character of the various systems of signs and their historical change are not worthy of painstaking study. The signs are far less important than the conceptions, and sink into insignificance by the side of them. Yet philology has occupied itself exclusively with the signs. This is a profound scientific mistake.

(3) The interpretation of language as a system of arbitrary signs coordinated with the conceptions has as yet not been fully appreciated by professional philologists. For this reason vague and mystical notions, as those of the "profound sense of language," of language as an "organic being," are very prevalent, especially among philologists.

(4) We regard language "historically," we look upon it as something miraculous, a venerable inheritance from our ancestors to be cautiously preserved and not to be attacked or transformed of our own authority. To improve a living language is considered so monstrous an idea that it has never been seriously discussed. Especially philologists oppose impassionedly such ideas, being intent upon conserving the inheritance in as unchanged a state as possible. But language is merely a technical means of the conveyance of thought, and the notion of its being supernatural, untouchable, is entirely erroneous.

The preceding statements are controvertible in some respect. But one can hardly dissent from Ostwald's view that of the two factors constituting language the conceptions are essential and the signs comparatively unimportant; yet "philology has occupied itself principally with the signs." Further, one must admit his statement that the prevailing notion of language as something miraculous, untouchable, is fostered in a great measure, if not chiefly, by professional philologists. It follows that tradition and training unfit them for being the architects of the ML.[3] For here the signs are selected "of our own authority" in conformity with logical reasoning and their "historical change" does not come into consideration. The treatment of the conceptions and the rational selection of the signs evidently appertain to the domain of logic. Hence logicians are best qualified for the construction of the ML, and systems proposed to play its rôle are to be estimated by the standards of logic. The writer, a lifelong student of the problem of the ML, finished some time ago the manuscript of a book on the scope and essence of the ML, treating all its aspects and offering suggestions for its construction. The work is entitled "Logos" and is intended to be submitted to the judgment of logicians. Its *leitmotif* is the concern for a system of "signs," or language, conforming to reason and free from the bonds of conventionality. It is this idea that the above title intimates; for "logos" means the "rational word." It must form the basic element of the ML in order to lead endeavors in its behalf to lasting success.

II. Sources of the Vocabulary of the Model Language

The ML must be so easy that an educated person can fluently read and un-

[3] This inference is not refuted by a recently published language the sole author of which is a professional philologist. It is claimed to be an improvement on the Language of the Delegation (LD) which is chiefly the work of the excellent logician Dr. L. Couturat. But it can be shown that in spite of substantial defects the LD is, on the whole, far better than the new language.

derstand any text after one short lesson or two and with the occasional help of a ML-national dictionary. Because of this requirement the words must be a posteriori, *i.e.*, taken from the natural languages, either international (itn., common to several principal languages) or national (ntn., belonging to one natural language), but not a priori, *i.e.*, newly invented. A posteriori words are far easier than a priori ones. The itn. words are easier than the ntn. ones, hence the former exclude the latter. Only when an itn. word does not exist for a certain conception, is this one to be rendered by a ntn. word. The number of itn. words is far too small for an efficient language, and lack of words for conceptions expressible with one word in the natural languages causes difficulties. Hence recourse must be taken to ntn. words.

The most important reason for excluding a priori words is that they would open the door to the whims of language inventors. But if the ML is restricted to a posteriori words, its whole vocabulary is independent of the fancy of authors. The itn. words are evidently given, but it is not so readily apparent that also the ntn. ones are determined, can not be selected by an author from any language that pleases him best. Certain words can only be taken from a certain language, as a few illustrations will elucidate. We are looking for expressions of the following conceptions or definitions:

(1) A matter of taste or a pursuit engaging unduly the attention and interest.

(2) Detriment suffered by undertaking something without the necessary experience.

(3) Damage done dishonestly by a laborer to the work entrusted to him.

The only words available for these definitions are: (1) *fad,* English; (2) *Lehrgeld,* German; (3) *sabotage,* French. It follows that the three needed expressions are determined, can not be any other ones but fad, Lehrgeld, sabotage. Yet these words are national. Previous publications of the writer furnish numerous other illustrations.

Sometimes one of several languages possesses for a certain conception a word which is the best because it is fairly univocal in that language while the words of the other languages are too ambiguous in these, or because it is the shortest or most euphonious one. For instance, we want a word for this definition: to draw a line through a passage in order to invalidate it. The English expression *to strike out* is too long; the German word *ausstreichen* is ambiguous in German and non-euphonious; but the French word *raturer* is precise in French and well-sounding. Hence the French word has to be selected.

Sometimes a word has to be taken from one language rather than from another one because the word of the latter conflicts with a word selected before. Even an itn. word has to give room to a ntn. word to avoid such a conflict.

The case that for a certain definition each one of several languages offers a word adequate in every respect is extremely rare. Unity of the ML will not be appreciably affected by leaving here the selection of the needed word to the taste of authors.

The ntn. words, too, are therefore determined, like the itn. ones. The objection that a language composed of words of various sources would be a *mixtum compositum* unfit for use is refuted by the most powerful and most expressive language, English, which contains Germanic, Latin, Greek, French and other root words.

Latin offers a rich source of words, which, as a rule, are also itn. But not all Latin words are itn. Systems using exclusively Latin words, such as Latino sine flexione, and other devices, are

fraught with difficulties. Because of the requirement of facility the words must be as itn. as possible. The degree of internationality of a word is measured with sufficient accuracy by the number of languages having that word in common. Another measure is proposed, namely the number of people in the whole world understanding that word. This number is unascertainable; the figures computed are fanciful.

When there are no itn. words, recourse is to be taken, in the first place, to the languages of the great nations, in the second place, to Latin and Greek, and, in the third place, to the languages of the small nations. The number of educated people acquainted more or less with Latin and Greek is larger than the number of nationals of a small nation.[4]

III. Extent of the Vocabulary of the Model Language

How many words are needed in the ML? The following considerations furnish the answer to this question. The main factors making for difficulty of the natural languages are unequal, or lack of, expressiveness and excessive multivocalness of the words. Very often one language has a word for a conception, and another language can express it only with a troublesome periphrasis. Consider, *e.g.*, the following conceptions.

A. 1. To look at a thing briefly, hurriedly; 2. To deter by a bold or confident manner; 3. To entrust a thing to the post office for delivery.

B. 1. To make one feel as if he were at his own home; 2. To declare a person incapable of managing his affairs; 3. Rejoicing at the misfortune of others.

C. 1. Self-confidence in dealing with others; 2. One who unlawfully takes the place of a wife; 3. Trickery having the show of honesty.

The definitions of A can be expressed with one word only in English: *to glance, to bluff, to mail;* those of B only in German: *anheimeln, entmündigen, schadenfroh;* those of C only in French: *aplomb, maîtresse, chicane.* An Englishman is at a loss how to express six of the nine conceptions. The same holds true of a German and Frenchman.

R. C. Trench[5] cites "words, which one people possess, but to which others have nothing to correspond so that they have no choice but to borrow these, or else to go without altogether." Many such words are treated in "Lexikologio," etc.[6]

A language possessing a word for a conception inexpressible with one word in another one is essentially richer in this particular instance. General essential richness of a language is represented by the number of conceptions expressible with one word. English is probably the essentially richest language. Synonyms do not make a language essentially rich, but merely more pleasing through variety of expression. They never cause misunderstanding, hence they need not be excluded. Synonymity in moderate degree is recommendable; it helps to obviate tedious repetition. But it should not be exaggerated since it is non-essential for expressing conceptions. Multivocalness, however, often due to essential poverty, must be avoided; it engenders difficulty.

Essential richness does away with the two main factors of difficulty of the languages. An extensive vocabulary does not necessarily tax the memory too much. No English student needs to remember all the words contained in the Standard Dictionary. It is a great fallacy that a language is so much easier, the fewer root words it possesses. Just the opposite is true. When the language of a writer has no equivalent for a word of another language, he has to apply the means of derivation, com-

[4] See "Logical Shape of the AIL," p. 3.

[5] "Study of Words," p. 119–121.

[6] Filologiala Temi; Raporto 28; Supplemento.

position, or periphrasis to express the corresponding conception. This is often an arduous task. A literary person needs a rich treasure of words laid down in dictionaries. If only a writer can find there the required words, his task is much easier than when he has to forge them. The ML must be adequate to translate all principal languages. It will remain inadequate so long as it lacks equivalents for their words. It is impossible to enhance the richness of a natural language, but there is no limit to the enrichment of a constructed language.

The answer to our question is now apparent. Besides a fair amount of synonyms so many words are needed in the ML that one is available for every conception expressible with a single word in any principal language. The ML would thus become the essentially richest language and thereby the easiest one. This aim may remain an unattainable ideal. Many ntn. words being unfit for the ML, sufficient a posteriori words are unobtainable. But for a great many conceptions adequate words can certainly be procured. They would bring us always nearer that aim. The natural languages, foremost among them English, show the way of approaching it more and more. English had no words for the conceptions "assurance resulting from self-confidence," "establishment for the diversion and instruction of little children," etc., and supplied these wants by appropriating the French and German words *aplomb* and *Kindergarten*. The ML can apply this procedure generally and systematically; it can adopt any suitable ntn. word. The task of enriching the word treasure in this manner requires many years' labor of many cooperating linguists who are competent, liberal-minded and familiar with the comparative expressiveness of the natural languages.

IV. Comparative Efficiency of the Languages, and Translation

Foreign words, such as *Weltschmerz, Zeitgeist,* are used in English for want of equivalents of equal impressiveness. To express clearly the idea of the first word in French one needs a lengthy phrase: *sentiment mélancolique causé par les déceptions de la réalité.* Such observations engender the surmise that some languages are more efficient than others. This can not be proved directly. There are, however, two criteria for estimating the comparative general efficiency of the languages.

One is the adaptedness of a language for the study of other languages. Intelligence, zeal, opportunity, etc., being equal, foreign languages are acquired better by some nationals than by members of another nation. This fact has but one explanation: the mother tongue of the former is a better means for studying languages than that of the latter. The instrument for learning a foreign language is one's mother tongue, and with a finer instrument better work is accomplished. This criterion can not be verified experimentally by reason of the above factors. Zeal, opportunity, etc., are unascertainable; intelligence, unmeasurable. The intelligence tests so fashionable in our day may be sufficient to establish imbecility, but are worthless for comparing normal intelligences, and even more so for contrasting intellects surpassing the average.

The second criterion is fitness for translation. The more faithfully one can translate with a certain language, the more efficient it is. The faithfulness of a translation is determined by the approximation of the retranslation to the original. This criterion is verifiable by an experiment. Before describing it we must show the requirements of good translation.

A good translation must, in the first

place, convey fully and exclusively the ideas of the original and, in the second place, preserve its linguistic characteristics and beauties. The second requirement can only be fulfilled by translating literally, by imitating, as far as possible, even the idioms. These may be divided into (1) pure idioms and (2) slightly idiomatic phrases. Literal translation is inapplicable to the former. They have to be rendered in some logical manner or through exactly corresponding idioms of the translating language. The latter mode of translating pure idioms is the better, more genial one. Far more frequent than these are the slightly idiomatic phrases, and they are well intelligible in literal translation. Rendering them logically deprives the translation of the beauties of the original. The languages obtain their charms by their peculiarities, by their slight deviations from strict logic. Too much of it is annoying. Faithful imitation of the original is therefore to be applied when it causes no misunderstanding. The limit to which one may go is set by the intelligibility of the translation and by the norms of fairly good style of the translating language. Literal translation offers a double advantage: it is far easier than the logical one and reveals to the student far better than the latter the true character of the language translated.

The preceding considerations lead to the following principle of translation: *In translating model prose one must follow the original most faithfully, word for word, going even as far as to observe the same order of the words, provided only that the translation is well intelligible and the norms of fairly good style of the translating language are not infringed.*[7]

Compliance with this principle is particularly important regarding the ML. For one of its objects is to reveal the character of a language to all educated people speaking different mother tongues. Pure idioms must be rendered in some logical manner since the ML possesses no corresponding idioms. In all other respects literal translation is to be applied. Its advantages mentioned before are here even more pronounced.[8]

Our experiment can now be appreciated properly. An author competent in languages A, B and C translates an original of A into B and C in conformity with our principle. The two translations are retranslated into A, the B-translation by a second author and the C-translation by a third one, both unacquainted with the original. Language B is more efficient than language C if the translation from B deviates from the original less than the retranslation from C does. The experiment is less reliable when both retranslations are made by one and the same author.[9]

In greater adaptedness for translation may lie one of the reasons why some natural languages possess a literature of translation surpassing quantitatively and qualitatively the literature of translation of other languages.

[7] Exhaustive Text Book, p. 17.
[8] Lektolibro, p. 22.
[9] Supplemento, p. 1.

TO-MORROW'S GASOLINE?

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This question of the duration of the oil supply has been discussed so often that another article may seem unnecessary, but if a few more people are set to thinking by this attempt, the time and effort necessary will be well repaid. Each of us looks at the problem from a slightly different angle and so something may be contributed to our general knowledge of the subject.

It is useless to say that the petroleum supply will fail in five, ten or any other definite number of years because such predictions have been made again and again and the coming in of a single gusher in a new field will entirely upset all calculations; but one thing is as certain as anything in the physical world can be and that is, we have to-day less oil than we once had and to-morrow we are going to have still less, because we can not "eat our cake and have it too," no matter what the average person thinks. Some day the domestic oil barrel will be empty—and then what?

It is unthinkable that we must some time, perhaps within the lifetime of even some of the older of us, throw all our automobiles, airplanes and other gas-driven necessities onto the scrap heap. We can not believe that a civilization so largely founded on the internal combustion engine will be wrecked for want of materials to drive that engine. But what are the probable future sources of such materials and what is the probability that they will be developed in sufficient quantities to meet our needs as gasoline fails?

Men engaged in the business of refining oils and producing from the fields do not seem to be worried about a future supply. One man of prominence said a few years ago, "Fear of exhaustion of the world's supply of petroleum is a bug-a-boo. There is plenty of petroleum and will be for a long time, but the question is, is the United States willing to pay the price for an adequate share of the world's supply?" A chemist of one of the world's greatest refining companies remarked that his company had oil enough in sight to take care of their refineries for many years to come, and yet the Geological Survey told us in 1920 that we had petroleum in the United States to last about twenty years more, that is to say that by 1940 our native supply would be practically all used. Such predictions have been changed from time to time, the limit has been extended, but already we are importing heavily from Mexico and it is believed by many, who should know what they are talking about, that we have already passed the peak of our production and are on the down grade. The pessimistic predictions of the Geological Survey were partly based on the assumption that no wells would be productive if drilled deeper than 2,700 feet, but to-day in the California field we have wells giving large yields from depths of over 5,000 feet. Yet no matter how many more fields we discover, how deep we drill our wells, there must be a limit somewhere; and yet there seems to be no limit to the number of automobiles we can build and sell. The curve of production of gasoline from native sources is sure to fall, while that of motor cars is rising.

Efforts to find oil in our island possessions have not been a success and after

a five-year effort one great company has withdrawn its explorers and given it up as a bad job. There is plenty of oil in Canada according to the incomplete surveys that have been already made, but much of it is almost within the Arctic Circle and the difficulties of getting it out of the ground, refined and to the market are so considerable that we can not depend on the Canadian supply for some time to come, if ever. There is plenty of oil in the world, but it is not within the boundaries of the United States, and since we have here so many more automobiles than all of the rest of the world, the outlook for us is not so good. Russia has probably more oil than we have and the same may be said of other countries, but if oil must be brought across the Atlantic or Pacific to our refineries the outlook for gasoline at anything like present prices is none too hopeful. Some day we may be paying fifty cents or more for gas and then many relatively poor people must lay up their little cars, unless of course we scientists can do something about it.

The general public has an almost childlike faith in the chemist and engineer and believe that we can take rabbits out of hats and pick diamond rings and first-class watches out of the air, but it takes time to set up the magician's table, and also it costs a lot of money. To fill the almost empty oil barrel is our task and it will be accomplished, but the difficulties are much greater than people think and much hard work must be done and much money spent before our task is finished. Furthermore, our present oil barrel has a number of leaks in it, so it would seem that the most logical thing to do at present is to stop up the holes, making what we have last as long as possible and give the scientists a fair chance to make good on the public expectation. Let us see what some of these leaks are and what can be done about them.

It has been estimated by various students of the problem that a very large percentage of the oil of any field is left in the ground. Wells are not completely emptied; they become flooded with water and other causes rob us of much of the oil we might expect. Some put the amount left in the ground as high as 80 per cent. of the total in the field. Now how are we going to get that 80 per cent. or some good portion of it? Some have tried flooding to raise the oil, but this eventually spoils the wells. Compressed air has been tried, solutions of soda ash have been poured down old wells in the hope that the oil in others might be increased in flow. Many other tricks have been tried but thus far with comparatively little success. We may hit upon some scheme to make our fields yield better, but as yet the prospect is not very promising.

There are other things we can do, however, every one of us. For example, we may conserve oil on the car; we can make a gallon give us more miles and can stop waste in other ways. It has been calculated that there is enough latent energy in a gallon of good gasoline to run a Ford car 480 miles on a level hard-surfaced road on a day when there is no wind. The writer does not know who made this calculation or how near the truth it is, but granting for the sake of argument that it is true, this means that we are getting an efficiency from our gallon of gas of but 4 per cent., as our average is somewhere near twenty miles. The steam engineer and the electrical engineer, the chemical manufacturer, etc., would feel that a 4 per cent. yield on any process was pretty small, and while we may never expect to get 100 per cent. of the energy from a gallon of gasoline in terms of useful work it is safe to say that our automotive engineers will not long be satisfied with our present efficiency, especially in view

of a failing petroleum supply and rising prices.

We are wasting large quantities of petroleum in our city gas plants. Gas in earlier times was made by the distillation of bituminous coal of high volatile content, and such gas had high lighting powers. Then the cheaper and more efficient water gas process was discovered whereby steam is passed over incandescent carbonaceous matter and a gas results which is composed chiefly of carbon monoxide and hydrogen, both of which burn with a non-luminous flame. The law demanded, and I believe still does, that city gas should have a definite illuminating power, and to achieve this the makers of water gas had to mix with their product a certain amount of oil gas made by the destructive distillation of petroleum. Since to-day we use gas almost entirely for heating or industrial purposes and almost never for lighting, the illuminating value of a gas is of little concern to us and this ancient legislation should have been repealed long ago and the petroleum used in the gas industry released for other and useful purposes.

Higher compression engines will enable us to use the higher boiling constituents of petroleum. Some of us complain that we now have too much kerosene in our gasoline, but the engines of improved design should be able to take care of kerosene all right. The knocking of the engines with these higher boiling substances has been one reason why they have not been more used in the past, but antiknock preparations seem to be doing away with this difficulty. There has been some hesitation in using such antiknock preparations as tetraethyl lead, used in "ethylgas," because of the serious danger of poisoning, but since the danger is recognized and precautions taken against it there seems to be no reason why it should not be used, and thus much material is thrown into the market for our use which was of little value a few years ago.

The writer does not believe that the most efficient type of carbureter is on the market; improvement can still be made. We may expect that the designers of the future will give us cars, the mileage of which per gallon of gas will exceed the sweetest dreams of present-day motorists. Indeed, a statement was made several years ago in one of the scientific journals that there was then a carbureter possible which if installed on the old-fashioned Ford cars would have saved enough in a year on the gasoline bill to allow the purchase of 75,000 more Fords. If this is true Mr. Ford and Mr. Rockefeller should get together and talk things over.

Another direction in which we may save gas is in the use of smaller and lighter cars. There is much progress being made in this direction and yet other countries seem to be doing better than we are because of the greater cost of gas, and some of the mileages they have achieved on a gallon of gas have been remarkable. During the war, when it was necessary to save for the needs of our overseas forces, it was not considered good form to leave an engine idling, and yet we seem to have forgotten our lessons learned at that time to such an extent that much gas is being wasted in that way. The writer always has a feeling of disgust at seeing a car standing still with the motor running while the owner is passing the news of the day in some store or office. If the car owner could realize that by wasting gasoline he might be depriving himself or more certainly his children of the pleasures and convenience of cheap gasoline he would not be so careless.

Running our trains and ships with crude petroleum may be convenient and cleanly, but it is wasteful, as we have other means of propulsion that are

about as good. The development of the steam turbine for the sea, the increase of the use of electricity for the shop and for land traction would seem to make it entirely unnecessary to use petroleum either for traction or in the factory. It would seem far better to save this for our cars and trucks. Heating our houses constitutes another waste of petroleum, and it is safe to predict that those who are now enjoying the freedom from work which this method of house heating makes possible will soon again be shoveling coal and carrying out ashes as of old. Perhaps we may be driven in our cities and small towns to some form of central heating which will do away with household furnaces entirely. Why not? If we can pipe water and gas into our houses, take away the sewage through pipes and bring in electricity over wires, is it too much to think that we will some day have sense enough to pipe heat into our homes and places of business from some central plant? Then this waste of petroleum will be eliminated and our oil still remaining will be conserved a much longer time.

But granting that the oil is being exhausted and that the end will come some time, what seems to be the most likely substitute? It is, of course, impossible to go into much detail concerning the several substitutes that are possible, but they may at least be indicated, and of these alcohol is the first.

Alcohol in place of gasoline has many advocates. Possibly they feel that filling the gas tank as well as the driver with the "joyous juice" may add new glamour to motoring. The rest of us have our doubts. But it is quite probable that alcohol will play a large part in replenishing our supply of motor fuel, and yet there are some properties of the substance that make it much less desirable than gasoline. In the first place is the fact that an engine starts badly on alcohol. This difficulty may be overcome by the use of ether for starting because if cheap alcohol is available we will also have cheap ether. Furthermore there is not the same energy in a gallon of alcohol as in a gallon of gasoline, so we will have to stop at the filling stations more often. It is also a question whether alcohol can be produced in large enough quantities, although it can be made from almost any organic material. Almost any vegetable matter can be changed into sugar and when this is treated with yeast nature will take its course, a fact well known to the home brewer and distiller. As one old lady once remarked when she was listening to a lecture on the wonders of chemistry, "What is the use of trying to make people temperate when a man with a buck saw can get drunk on a piece of fence rail?" So easy is it to convert vegetable matter into alcohol, even such material as cellulose, that a single copy of the Sunday edition of your favorite paper might be converted into enough to cause the partaker thereof to become most optimistic, for a time at least. If we were to use food crops for alcohol, the amount of land that we would have to employ might be more than we could spare and still feed our people. All sorts of waste material from our sawmills, straw, grass, cornstalks, cotton plant wastes, pea vines, and a thousand other things can be used which now have no value, but the question is one of cost; and even if all such waste should be utilized there would not be enough alcohol to take care of all our need for motors. The Germans have developed a special kind of potato for alcohol manufacture, a potato full of starch, large but flavorless and unfit for food, but here again the question of sufficient land enters in. Perhaps some sort of tropical vegetation might be used and the center of alcohol production may be the dense jungles near the equator where vegetation grows so rapidly that no form of human life can thrive

in such regions until it is cleared. Oh, yes, we chemists can make you motorists a lot of alcohol. But we predict you won't like it as well as gasoline and you won't like the price either until very large scale production is reached.

Shale oil, distilled from the great mountains of shale in some of our western states, offers some most interesting possibilities for a future source of petroleum products. We need lubricating oils as well as motor fuel, and these shales will furnish them while alcohol does not. Petroleum has been made for a long time from shale, especially in Scotland where so little of anything goes to waste. The Scottish shales lie fairly deep in the earth, are in thin beds, much folded and irregular so that mining is difficult. But it seems that if the Scotch can make a success of the industry under their working conditions we can utilize our shales which are in mountain-like masses in Colorado, Utah, and other places. Instead of mining and hoisting the rock to the surface we have in many places only to blast it out from the hills and drop it by gravity to refining plants along the railroads.

It has been known for a long time that oil shales contain combustible material, the fact having been discovered by two enterprising miners of pioneer days. These gentlemen built themselves a nice log cabin with a fine fireplace and chimney. Fireplace and chimney were laid up with some flat black stones they found in the neighborhood; when they built their first fire, fireplace, chimney and cabin went up in flames, a discovery of the properties of oil shale which we might compare to the Chinese discovery of the delights of roast pig—convincing but expensive.

It is calculated that the oil shales of Colorado alone will yield twenty billion barrels of crude oil much like petroleum, equivalent to about one billion barrels of gasoline, and Utah can furnish as much more. There are other promising sections also. Another survey brings us the information that there is ten times as much oil in the shales of Colorado as has been produced in the United States since 1859, the year of first production. This is certainly good news to a nation clamoring for more oil, but we must not forget that it is a long way from the oil in the mountain to the gasoline tank on our car. In the first place we must have a whole army of miners, perhaps I should say quarrymen, as it is more of a quarrying than a mining proposition, to get the shale out, and it is estimated that as many men will be required as are now employed in the present coal industry. The development of shale oil would almost at once take up the slack in the coal-mining industry, which seems to be suffering from the fact that we have more miners and mines than we can profitably use. Then we have the difficulty of distilling the oil from the shale, and this will demand a manufacturing organization much like the present for refining petroleum. Probably the refining facilities of to-day will be applied to a very large extent. Certain by-products of shale would be very profitable, such as ammonium sulfate, flotation oils, etc., and the value of these would greatly reduce the cost of manufacture of our gasoline and lubricants. But it is evident that under the most favorable circumstances it will be a long time and a vast amount of money must be spent before the shales can furnish as much gasoline as we are now using each year. Shale, however, seems to offer a source of gasoline which will be very dependable once it is developed, and we do not need to fear that the supply will fail for a long time; many of us believe that here is our most probable source of oil in the future.

The distillation of coal tar and the by-products coking process offer a considerable quantity of what is called distillate,

a liquid consisting largely of benzol and toluol, and this has already been used with considerable success in internal combustion engines, either alone or mixed with gasoline. Indeed many of our filling stations are selling blended gasoline of which distillate is a considerable constituent. There seems to be some difference of opinion as to the value of distillate in an engine: some say that there is more carbon formed, spark plugs become fouled more quickly than with straight gasoline; yet others say they have used the substance for years with no more trouble than from gasoline. But if all the coal produced in our year of highest production had been coked by the by-product method and all the tar distilled for its maximum yield of distillate, only about 70,000,000 barrels could have been made, or enough to take care of our motor needs for the year 1917. But to-day we have certainly a third more cars than at that date and so it is evident that under the most promising conditions distillate will not meet our demands. It will probably be very useful as far as it goes and will greatly help to fill an oil barrel which contains alcohol, shale oil and other things equally interesting. It should be added that at present the total production of distillate meets about 2 per cent. of our gasoline demand.

We have believed for years that if we could make coal combine with hydrogen and if we could get cheap hydrogen we could synthesize hydrocarbons like those found in petroleum. At last in the Bergius method such a process has been worked out and is being operated profitably in Germany. There, of course, it does not have to compete with gasoline as cheap as we have it here in the United States. Cheap hydrogen we can obtain from the water gas process. In most common fuels, with the exception of anthracite coal and coke, the ratio of carbon to hydrogen is about 16 to 1, while in the hydrocarbons which make up petroleum the ratio is about as 8 to 1. Now the question arises, if we could increase this ratio in coal could we not obtain the hydrocarbons? Bergius undertook the solution of the problem and has made a success of it. In his process the coal is broken up into small grains about the size of wheat grains, then is mixed with a little crude oil or tar and a catalyst, in a strong cylinder, and over it is passed water gas under a pressure of 3,000 pounds to the square inch and at a temperature of about 800° C. The result is a liquid that is much like crude petroleum except that it lacks some of petroleum's low boiling constituents. The exact nature of the catalyst is not known, although it is probably one of two types, either a mixture of copper, manganese and cobalt compounds or copper, cobalt and uranium as oxides, as the finely divided metals or both. In a recent experiment carried out at the Coal Conference of 1928 in Pittsburgh, 104 gallons of crude oil were obtained from a ton of coal. From this, forty-five gallons of good gasoline were obtained by distillation, also fifty-five gallons of oil and four gallons of tar. The oil in turn yielded twenty gallons of spindle oil, thirty gallons of high-grade motor oil and five gallons of cylinder oil and grease. The gasoline did not knock when used, probably due to the presence in it of considerable quantities of unsaturated compounds, more than in gasoline made by straight distillation of petroleum.

The importance of this Bergius process may be assumed from the rumor that the patents for the United States have been purchased by one of our great refining companies. It will, without doubt, be placed in operation as soon as the price of natural gasoline reaches a high enough point to make the new process pay. One writer has said that the "Bergius process is like a large endow-

ment policy for the future of the motor industry." It is a nice thing to think about and it is quite probable that much of our gasoline of the future will be made by this process. Possibly it will be the universal process, but the writer feels that all of the various possibilities for making gasoline substitutes will be exploited and we will fill the empty gas barrel with many different types of materials, all of which will serve to help carry the burden.

Some research has been carried out on methods of making gasoline synthetically from acetylene. This is probably only a laboratory curiosity at present as the cost would be prohibitive. Also some success has been attained by Fischer, in Germany, on a process of combining carbon monoxide with hydrogen by passing them at low pressure over suitable catalysts of iron or nickel. This has already resulted in the commercial production of methyl alcohol and other useful products as well as a series of hydrocarbons. There is already a product of this process called synthol, used as a gasoline substitute, and we are waiting for further developments with great interest. Some believe that these reactions have only theoretical value and that they can not be worked out on a commercial scale, but one great argument in favor of such a process as this of Fischer is that it can be carried on by the common city gas plant. The manufacture of gas is a more or less seasonable operation as much more gas is consumed in winter, hence expensive equipment has to remain partly idle in the summer. Now if such plants could be utilized for making gasoline in the summer, full-time use of the plant would be possible, and any organization is most economical when being operated at capacity. Equalization of the load on the gas plant would be a good thing all around.

One of the officials of the Bureau of Mines expressed the feeling that synthetic gasoline will surely be on the market as soon as it is needed and that the industry will be so developed that it will ultimately meet the full demand for motor fuel. The man in the street will probably never realize that the fuel he is purchasing never came out of the ground, so gradual will be the change from one kind to the other. No one substance, no one process will meet the fuel situation completely, but at first all will be working together, until one process shows its superiority over the others and the weaker drop out of the race.

Every human need thus far has been met in some way or another, and the replenishing of the gasoline supply will be no exception. We feel confidence that this need will be met and met fully. Scientific and engineering progress has been so amazing in the past fifty years and the rate is to-day being so accelerated by research that we can never doubt the future. But research costs money and takes time; it demands the hardest thinking. And to solve this great problem of the gasoline supply tomorrow we must have the most cordial cooperation between chemists and engineers, and the men of money must be prepared and willing to furnish an almost incredible number of millions which will be eventually returned to them with many other millions added.

VITAMINS AND THE WORLD OF PLANTS

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For nearly seventeen years it has been known that animals, including the human race, require in their diet minute quantities of organic substances of unknown composition—termed vitamins—before growth can occur or health be maintained. By an ever-increasing number of searchers these essential substances have been investigated, in order to find where they exist, to learn their effect on the body and to isolate them in a pure state. The influences, however, which lead to the production of these vitamins have been much less thoroughly studied than the effects they cause; nevertheless, knowledge is gradually accumulating which may prove of importance in food production.

While success in the isolation of these substances has been small and we can not yet point to any group of chemicals and say "These are the vitamins," the major effects on the animal body of their absence in the diet are fairly well known. The particular functions which are stimulated into action by their presence—whether one vitamin acts on the nucleus of all the cells or another on some special organ of the body—are not yet perfectly understood but the information that has been gained has played no small part in that "newer knowledge of nutrition" which is becoming so widely diffused.

Because the composition of the vitamins is not known, they are named by the letters of the alphabet. The first is A and its function is "growth-promoting." A constant supply is essential for growth in young animals, although it may be stored to some extent in the adult body. Absence produces also the disease of the eyes known as xerophthalmia. A is found in green leaves, in yellow fats and in liver oils, especially in cod-liver oil; vegetable oils, as a rule, lack it. B is called the water-soluble vitamin, and is now known to consist of two, very closely associated in nature—the anti-neuritic, which is tested by its power to cure paralysis, particularly in pigeons, brought on by a diet such as polished rice; and the growth-promoting B, which may also prevent pellagra. These are present in green leaves and in seeds; yeast contains large quantities. C is the anti-scorbutic vitamin which prevents scurvy. It is not found in seeds but is plentiful in young sprouts. Citrous fruits, tomatoes and green leaves contain it. D is the anti-rachitic, associated frequently with A. This vitamin prevents rickets in children and has a great deal to do with good bone growth. One of the chief sources is cod-liver oil, but ultra-violet rays, either from sunshine or produced artificially, may take its place. A little-known chemical substance, ergosterol, when irradiated with ultra-violet light, has the same effect in the diet as the vitamin. The last is E, without which reproduction in animals ceases. E occurs in oil extracted from the germ of the wheat seed and in some green plants; it has only recently been investigated and reported.

From the observation that the sources of the vitamins are found so frequently in plants, it seemed possible that the animal world might be dependent upon the plant world for its supply. Investigation has shown that "the vitamins present in animal tissue, and in products of animal activity have not originated there, but have been transferred from a vegetable source." The cod does not produce the vitamins which are obtained from its liver. The cod feeds on smaller

fish, such as the herring, and these in turn eat the planktons—floating worms and larvae—whose food consists of microscopic marine organisms, among which are unicellular algae called diatoms. It is the diatom which produces the vitamin, and this is passed through the various stages unchanged until it is concentrated in the cod-liver oil.

Thus the vitamins are formed outside the animal world, but are found in plants and in certain micro-organisms. Questions as to their production at once suggest themselves. How does the plant obtain the vitamins? Does it manufacture them or get them ready-made from micro-organisms? What conditions are best for their production, and is it possible to increase the vitamin content in the plants used for food? Does the plant or the micro-organism need these vitamins, or other similar substances, in order to live? These aspects of the subject have received comparatively little attention, but are not altogether unknown.

It may be asked why it is necessary to investigate these questions, if the ordinary diet of the human race supplies a sufficient quantity of the vitamins for good growth and health maintenance. Quite apart from the unsuspected facts of value which may be discovered—a condition which so frequently occurs when such investigations are made—it is becoming more and more evident that certain types of diet, not only among the rice eaters of the East or the millet eaters of India, but also in this country, show a deficiency in the vitamin content—a lack not sufficient to stop growth or to produce xerophthalmia or scurvy, but large enough to cause susceptibility to some of those minor ailments which so greatly cut down the efficiency of the individual, and which so quickly take the joy out of life. Attempts have been made, therefore, to trace back the sources of these vitamins and to find out conditions which are favorable for their formation.

An investigation was started along these lines to determine what it was necessary to feed the marine algae which produce the vitamin finally found in cod-liver oil. The first attempt to grow these diatoms in a solution of pure chemicals—an artificial sea-water—was a failure. Later, this was accomplished, and good growth of the diatoms in solutions free from organic matter was obtained; the diatoms produced vitamin A from solutions of pure chemicals. Similarly fresh-water algae, free from any trace of bacteria, were induced to grow in a synthetic solution without organic substances, and they also produced vitamin A. In the presence of sunlight these algae can form vitamins from purely inorganic constituents.

Certain algae will therefore grow and reproduce without any trace of organic matter, but this does not necessarily exclude the possibility of their rate of growth or their speed of reproduction being accelerated by the inclusion of organic substances in the solution in which they live. In the case of protozoa, microscopic organisms belonging to the animal world, it has been claimed by some investigators that organic matter contains an unknown factor—"substance X"—which is essential for their growth. This statement has been disputed by others, who hold that the unknown substance is not essential for the protozoa, but that it stimulates their life processes. It is necessary to distinguish carefully between those factors which are essentials—as vitamins are essentials for animals—and those which are not necessary for life, but which may increase the rate of growth, the speed of reproduction or the quantity of some substance formed within the organism.

If we keep this distinction in mind, and turn to the bacteria, we find that in general bacteria can not make use of carbon dioxide as a source of carbon, but are dependent on organic food for that element. Only a few, such as the sulfur bacteria, can do without the organic

material. It is particularly difficult, therefore, to find whether they need minute quantities of a special kind of organic matter which may act as an essential in a similar manner to vitamins, or even if traces of any substance act as a stimulant. There are many chances that the very small quantities needed are already incorporated in the organic matter on which the bacteria feed. Some attempt has been made to investigate this problem, but up to the present time progress has been slow and claims for the existence of such substances are generally regarded as unsatisfactory.

When we turn to the other side of the question and inquire if the bacteria produce the vitamins, we find considerable divergence of opinion. There are indications that bacteria not only manufacture the vitamins, but also produce various stimulating substances for the growth of plants. The theory has been put forward that it is bacteria alone which are capable of synthesizing the vitamins; that they carry them to the green plants, and that the vitamin content of the plant is as incidental as that of the cod. This theory, again, has not received general support.

A large number of different species of bacteria have been tested for vitamin B, with results which vary widely. While it has been shown that certain species of bacteria produce comparatively large amounts of B, others show no effect whatever when added to the diet of animals. The absence of this effect is caused, sometimes because the species produces so small an amount that the animal can not eat enough of the bacteria to get the quantity of the vitamin it requires, and sometimes because the micro-organism lacks the vitamin entirely. However, the synthesis of B by bacteria seems to be of rather general occurrence, although in varying amounts; there is little information concerning the formation of the other vitamins due to bacterial activity, and none at all whether a change of food or conditions would increase the vitamin production.

At the present time bacteria as food figure little in the human diet. It is true we use the products from a few bacterial transformations—vinegar is produced from alcohol by *Mycoderma aceti*, and Metchnikoff introduced the drinking of milk treated with the Bulgarian bacillus in order to change the bacterial flora in the intestines; but as food, *per se*, bacteria have been neglected. When we consider the amazing changes which have been brought about in animals by selection and feeding, and the ease with which bacteria can be produced, the possibilities of "bacterial farms" can not be dismissed altogether as a factor in the food supply of the future.

That micro-organisms may yet find a place in the diet is indicated by the daily use of yeast by thousands of people in this country. Yeast cells, although far larger in size than bacterial cells, are still microscopic in dimensions. Used for ages in the making of bread and in the fermentation of sugars, early in the study of vitamins certain yeasts were found to contain large quantities of the water-soluble B, and again the questions needed answering: Do the cells produce the vitamin or do they get it from their food? Is B needed for the growth of the yeast itself or is an organic stimulant necessary for the life and reproduction of the yeast and for the formation of the vitamin?

Before this discovery of vitamins, it had already been pointed out that it was necessary, in order to get good growth in one species of yeast, to supply organic matter along with the needed sugar and inorganic salts. The unknown substance in the organic material causing the stimulation was given the name "Bios," meaning growth. It occurred in widely different kinds of organic matter and was even present in the yeast itself, for the cells when crushed and added to the inorganic salts produced the same remarkable acceleration of reproduction.

Bios proved to be a stimulant but not

an essential for yeast life. True, the cells would multiply only very slowly when grown in a medium consisting of inorganic salts and cane-sugar, but reproduction did take place. For some time it was not known whether this multiplication was due to a trace of Bios in the sugar, even when it was carefully purified, but later, a simple sugar was manufactured from pure chemicals which the yeast used, growing without added organic matter. Bios, accordingly, did not act towards yeast in the same way as vitamins with animals: it was a stimulant for yeast, while a vitamin was an essential in the life of the animal. The proposal to include Bios as one of the vitamins was therefore dropped.

A large number of plant and animal tissues which contained vitamin B also contained the substance Bios: the suggestion was made that B and Bios were identical and that the same substance was the stimulator for yeast and the essential for animals. A method for the measurement of B, depending upon this and promising to be much more rapid than the feeding of animals, was worked out from the quantity of yeast produced by the vitamin-containing material. The method, however, proved to be unreliable, for evidence accumulated pointing to the separate existence of B and Bios. Investigations were published from many different sources to show that vitamin B and Bios were not only occasionally found separated in different substances, but also that chemical actions which would destroy the one were frequently harmless to the other.

All attempts to isolate vitamin B had failed, but Bios after long research gave up some of its secrets. In 1925 there came reports from three different laboratories to show that Bios was not a single substance; it contained at least two distinct parts—Bios I and Bios II—which could be separated from each other. Neither of these fractions could stimulate the yeast alone, but together they were as effective as before separation. Both Bios I and Bios II were shown to be different from either vitamin B or C; the chemical treatment which resulted in the separation destroyed entirely vitamin B.

The two Bios fractions were found to occur, sometimes together and sometimes apart, in a wide variety of animal and vegetable products. At the University of Toronto, tea siftings were discovered to contain large quantities of Bios I, and after repeated attempts a crystalline substance having the properties of Bios I was isolated from the tea. This proved to be an organic chemical —inosite—a substance which is known to occur frequently in plants, especially in the growing parts. The commercial product was found to have the same stimulating action on the growth of yeast, when mixed with substances containing the unknown Bios II, as the inosite isolated from the tea siftings.

There are two facts regarding the inosite which are worth noting. First, the yeast uses a definite amount of the inosite for each cell, and that amount can be recovered quantitatively from the cell at the end of its growth—a condition similar to a chemical "catalytic action" in which a substance starts or increases the speed of a reaction but is not itself used up. Secondly, although the yeast grown without Bios I manufactures it slowly, yet when mature the cell contains only about half as much as it holds when a supply has been furnished. As it has been shown that yeast grown without organic matter produces the vitamin, it is evident that the presence of Bios I is not necessary for the yeast to form B, unless the inosite is formed in the cell as a preliminary step in the building up of the vitamin. It may prove that inosite formation is such a preliminary process, for the vitamin supply of yeast grown without organic matter seems also to be about 50 per cent. of the usual vitamin content of the yeast cell.

The problems in connection with the green plants are even more difficult to solve than those of micro-organisms. Plants take longer to grow than bacteria or yeast, and they are much more highly organized. The quantity of a vitamin not only changes from plant to plant, but also varies in the different structures, leaf, stem, root, flower or seed. Although little more than an approach to the fringe of the subject has been effected and the problems indicated only, yet enough has been accomplished to bring out possibilities of influencing future agricultural practices.

Shortly after the discovery of the existence of vitamins necessary for animals, a claim was put forward for similar essential substances for green plants. These unknown substances were called "auximones"—meaning growth-promoting. Wheat grains which would grow in solutions of inorganic chemicals, responded quickly to additions of organic matter when part of the seed was removed after the wheat had started to sprout. This indicated that the seed might contain the auximone or plant vitamin. Water plants were therefore chosen which multiplied by putting out small leaves from the parent leaf. The new leaves separated from the others and in turn produced a new generation. These duckweeds, containing the characteristic chlorophyll of the green plant, failed to reproduce continuously in two well-known inorganic salt solutions, but on the addition of organic substances from farmyard manure or from the soil, growth was obtained. The results pointed to the conclusion that "all green plants require the presence of organic matter of a special kind for their maximum growth and development."

This statement was not allowed to pass unchallenged. At Iowa State College the same plants were tested in a large number of inorganic solutions, and it was found that by altering the chemicals it was possible to obtain a solution in which the duckweeds would reproduce and maintain their health and vigor without the addition of any traces of organic matter. The plants passed through hundreds of generations and no deterioration was shown. This removed the possibility that green plants needed organic substances as essentials, but left as an open question the stimulation of growth, or even the alteration of the plant content, by organic matter.

It was in 1840 that Liebig finally obtained the acceptance of the fact—discovered earlier by Senebier and de Saussure—that green plants acquired their carbon, not from organic matter in the soil, but from the carbon dioxide of the air. Thirty years afterwards, Grandeau indicated that at least part of the carbon might be taken in by the root, and later the presence of certain types of organic matter has been shown to stimulate strongly the growth of green plants. The effect upon the composition of the plant is not well known, and whether or not the vitamin content is affected has hardly been investigated; yet from the point of view of fertilizers in agricultural practice it is of primary importance to determine the effect upon the quality of the product. Agricultural improvement has in most instances given attention to improvement in quantity—in only a few cases where public demand has to be satisfied, or where private industry has set a standard, as in the sugar percentage of beets, has an increase in the quality of the product been the aim of agricultural practice. That this point of view may require changing in the future is quite possible, for there is some evidence that at least the vitamin content of the plant may be affected by the organic matter in the soil.

In India the observation was made that rice from different localities varied in nutritive value. The variation was traced to the soil in which the rice was

grown, and an investigation was started on the influence of soil upon the common grains of that country, of which one is millet. In Madras, millet is the principal cereal of millions of people, and in a restricted diet the vitamin value of the millet would be of considerable importance. This grain was therefore grown in three different ways: (1) on a soil which had received for years quantities of cattle manure; (2) on the same soil receiving instead of the farmyard manure, nitrogen and phosphorus and potassium as mineral fertilizers; (3) on the same soil without any additions. The seeds from the three plots showed no marked differences in size or chemical analysis, but when they were planted in a soil not especially rich in organic matter, the seeds from the plot which had received the farmyard manure produced much greater crops than the other two plots. Further, there was a large difference in feeding value—the vitamin B content of the seeds from the manured crop was greater than from the others. Wheat, treated in the same way, showed the influence of the organic matter on the next crop, and the vitamin A content was larger. It seems that in the organic matter of the farmyard manure there are substances which not only give the plant power to manufacture vitamins A and B, but also produce a stimulant in the seed which will influence the succeeding crop.

Experiments in this country failed to show consistent variation in the vitamin B content of wheat, when the soil was treated with different mineral fertilizers. Results were obtained over a series of years but with only slight indication that phosphorus fertilizers might be more favorable to the vitamin formation than potassium or nitrogen. The vitamin content of all the wheats in the series of experiments was low, but no trials with the addition of organic matter were reported. Climate, however, appeared to influence the quality of the vitamin formed. This, along with the differences in soils, may explain the large variation in the amounts of wheat required by different investigators for an adequate quantity of B in the diet. Whether the deficiency of the vitamin due to climatic and soil conditions will prove to be serious and whether it can be overcome by agricultural practice remains as a problem yet to be solved.

Although the importance of these vitamins in the diet of the human race is no longer disputed, attempts to increase the supply have been comparatively few in number. We have seen that these essential substances are not produced by animals, but are obtained by them from green plants or from micro-organisms, and that the problem of production has been scarcely touched. Certain types of marine algae contain large quantities of vitamin A, and this is concentrated in the fish which eat them. These diatoms can synthesize the vitamin from inorganic sources under the influence of sunlight, and fresh-water algae act in the same way. Many species of bacteria as well as yeasts can manufacture vitamin B. Green plants produce all the known vitamins, but in different plants and in varying quantities.

The problem is complicated by the existence of stimulating substances in organic matter which may affect the quantity of the essential vitamins formed. This is almost certainly the case with yeast, where the addition of Bios adds materially to the content of vitamin B. There are some indications, also, that on certain soils the cereals produced may vary considerably in vitamin content of A and B due to the presence or absence of organic matter. With the growing reliance upon mineral fertilizers, due to the lack of farmyard manures, the question may eventually become as important in the agriculture of this country as it is now in some other parts of the world.

PARASITISM AS A BIOLOGICAL PHENOMENON

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THE study of parasites and parasitism has in recent years developed into one of the important fields of scientific investigation. Increased knowledge has shown that parasites play a tremendous rôle in the production of disease. One has only to note the prevalence and morbidity of hookworm, malaria, yellow fever, sleeping sickness, typhus fever, amebic dysentery, to mention only a few of the more commonly known parasitic diseases, to realize that the great scourges which have decimated populations are of parasitic origin. It is largely the prevalence of parasitic diseases that has prevented the exploitation of the tropics, the richest and most productive agricultural areas of the world. The pathogenic bacteria are parasites in the strict sense of the word, and consequently most of the illness and death among men and animals is due to the activities of these organisms.

Not only are human beings and other animals subject to attack, but statistics record that one tenth of all crop products in the world are annually destroyed by parasites. Universities, government departments, endowed foundations, scientific societies and other agencies are maintaining staffs of workers engaged in study of the medical, veterinary and agricultural aspects of parasitic infestations. Many of these investigators are directing their attention to the protozoan forms, others to the several groups of parasitic worms, while a study of the insect parasites constitutes a special section of the field of entomology. As a result of these studies there has grown up so massive an accumulation of literature that in addition to the American *Journal of Parasitology* there are several English, French and German periodicals devoted entirely or primarily to the publication of results in this field.

It is, then, generally recognized that parasitism exists in nature and that it is wide spread. Few, however, clearly apprehend that it comprises one of the most distinctive categories of animal existence, and constitutes a discrete and characteristic biological phenomenon. Careful and critical study of large numbers of parasites, belonging to various classes of animals, has demonstrated that parasitism has certain basic and fundamental characteristics, no matter in what group of animals the parasitic habit may have been developed. The same general tendencies are manifest, similar attributes and relationships appear, and similar consequences inevitably follow the adoption of the parasitic habit.

The consideration of parasitism as a biological phenomenon, and investigation of its fundamental nature, origin and interrelations, may yield results of far-reaching consequence. Experience has shown that not infrequently researches into the purely scientific and theoretical aspects of natural phenomena have led to broader and clearer conceptions and have proved more valuable than the narrowly conceived and immediately practical application of existing knowledge. It is this concept that is here reviewed: *i.e.*, the biological aspects of parasitism, the extent to which it occurs in the animal kingdom, the origin and development of the parasitic habit, the evolution of the complicated life histories found among parasitic

forms, the effect of parasitism upon the parasite and upon the host, the relationship of parasitism to disease, and the factors of susceptibility, tolerance and resistance to parasitic infestations.

A parasite is an organism which lives at the expense of its host, giving nothing of value in return. The term parasite was first used to designate those individuals who frequented the tables of the rich and influential in ancient Greece and who courted these favors through fawning and flattery. The condition, then, has always been an opprobrious one.

The study of parasitic phenomena constitutes a special section of that new and at the same time extremely old field of ecology. It deals primarily with animal and plant associations, with the conditions and social relations which exist among living organisms. There can be no question but that it is as old and as universal as animal associations themselves. In any community numerous plants and animals live together and parasitism is an outgrowth of this association. Certain individuals find it easier, more pleasant and profitable to prey upon society than to earn an honest living.

The parasite may be a bacterium, a fungus plant or an animal. The bacteria are simple organisms with little morphological differentiation, characterized and identified by their metabolic or physiological reactions. They are primitively saprophytic, securing their food by the absorption of nutrient fluids, and consequently little modified by parasitism. The fungi, while probably derived from chlorophyll-bearing plants, have secondarily become saprophytic. Physiologically they are similar to the bacteria, and in both the effects of metabolism are analytic rather than synthetic. In a general way, therefore, the characterization of the bacteria may be applied to the fungi. The results of parasitism observed among the lower plants appear also in the animal kingdom, but in a more extended and amplified degree. It is here that the most conspicuous changes have occurred as a result of parasitism, that the clearest and most definite evidence is available for the study of parasitism as a biological phenomenon, and that the best opportunity exists to observe and measure its effects. Consequently the present discussion is chiefly concerned with parasitism as it occurs among animals.

For convenience we relate the parasitic forms in groups but frequently such groupings are not natural taxonomic or systematic ones. On the other hand they are in most instances ecological or physiological groups. The ectoparasites, endoparasites, temporary or facultative parasites have nothing in common except physiological attributes, and a classification based on these properties is obviously an ecological or bionomic one.

Parasitism in the animal kingdom is an almost universal phenomenon and no great group of animals is without its parasitic members. While there are relatively few parasitic vertebrates, aside from those belonging to the human species, the same is unfortunately not true for the invertebrates. Beginning a survey at the top of the invertebrate kingdom, a glance at the arthropods will show innumerable forms that have adopted the parasitic habit. The late Sir Arthur Shipley, in his recent paper, "Parasitism in Evolution," gives a splendid account of the parasitic insects. The lice and fleas constitute the subject of a large and special branch of entomology; the mites and ticks are minute arachnids without any external signs of segmentation; and these forms are augmented by enormous additions from the Crustacea. Living things from the largest elephant to the smallest rosebush are infested by the myriad parasites which belong to this phylum. Some of

the forms, indeed, are hard to recognize, since we find such extreme modifications in body form that the original characteristics are largely lost. Sacculina has become so modified as a result of parasitism that only a study of its life history demonstrated its true crustacean nature, and the linguatulids are so changed that even to-day there is much difference of opinion as to whether they are arachnids or polychaete annelids.

An astounding number of the worms are parasitic. Especially is this true among the nematode round worms. Hardly a species of metazoan animals exists which does not harbor some nematode species. Indicative of their prevalence is the recent volume of several hundred pages by Yorke and Maplestone on the nematode parasites of vertebrates. While the information is less complete, there is abundant evidence that the invertebrates are infested no less than the forms with a vertebral column. The majority of the flat worms are parasitic, and two of the classes, the trematodes and cestodes, are entirely so. These worms infest almost if not every species of vertebrates and their larval stages are frequently passed in invertebrate hosts. So far as we know all digenetic trematodes undergo parthenogenetic reproduction in some mollusk, while the cestodes frequently use other invertebrates as intermediate hosts.

Turning then to the most primitive phylum, the Protozoa, we find that every class has parasitic members and that one group, the Sporozoa, are entirely parasitic. It is estimated that there are no less than ten genera of parasitic sarcodinids, and an even larger number of parasitic flagellates; while the ciliates, usually regarded as independent, free-living forms, have a dozen genera that contain parasitic members. The Sporozoa is a group with no genetic entity, but consists of various sarcodinid and flagellate forms that alike have assumed the parasitic habit and reproduce by multiple fission. Actually it comprises a heterogeneous collection of forms of diverse ancestry which reproduce at some stage by sporulation. The Gregarinida and Coccidia sporulate at the end of a life cycle, have ectospores and manifest flagellate stages; the Neosporidia (Cnidosporidia, Sarcosporidia and Haplosporidia) sporulate throughout life from endospores and have amebic stages. The "binucleate" blood-inhabiting Protozoa are apparently descended from both (1) uniflagellate forms, originally parasitic in the gut of invertebrates and (2) heteromastigote forms, originally parasitic in the intestine of vertebrates. There are thousands of parasitic protozoan species described, and probably more as yet unknown.

Every species of animal harbors one or more parasitic species and the smaller parasites frequently occur in enormous numbers. With these data before us there can be no escape from the conclusion that there are more parasitic than free-living species in nature, and more parasites than free-living individuals. Such a conclusion may at first appear startling, but a careful study of the subject justifies the statement.

The next question to consider is why and how so many forms have become parasitic. There are really only a few basic conditions of existence, and as Schiller long since pointed out, "The edifice of the world is only sustained by the impulses of hunger and love." The most powerful animal instincts are those concerned with food getting, protection and reproduction. All these instincts are concerned with and involved in the development of parasitism. Animals must either shift for themselves or depend on others. They must have a source of food supply, whether they are herbivorous, carnivorous or parasitic. They may prey on plants or upon each

other. Animals in the same habitat strive for sustenance, for the means of existence. The stronger prey upon the weaker and the fittest survive. But there is another aspect of the picture. Some of the small and physically weak are able, for various reasons, to impose themselves on the stronger, and these cunning, socially clever individuals live at the expense of their neighbors.

Parasitism is a gradual and progressive adaptation to a dependent condition on the part of the animal or species which adopts this mode of life. It arises, at least in most instances, as a result of an attempt to secure either protection or food. In the end, the parasite obtains both from the host. The adaptation may be slight or very extensive. Certain species are temporary parasites, forsaking the host after a satisfying meal, while others become permanent dwellers near or at the source of supply. Other species are merely lodgers, deriving nothing more than protection from their host, with frequent transportation to new pastures as the host moves about. Then there is the condition of symbiosis, living together, either as commensals or mutualists. In the former case one species alone benefits by the association and the other receives nothing in return. In the latter case both benefit by the arrangement. It seems the usual trend of affairs, however, that when a species becomes a lodger, sooner or later it begins to attack its host, possibly when other food sources become scarce. Finally, to secure safer and more advantageous conditions of life, the ectoparasite penetrates into the body of the host.

External parasites can exist only in a fluid medium unless they possess a resistant, impermeable body covering. Aquatic animals may have soft-bodied ectoparasites, but if they leave the water, evaporation will cause these forms to dry up and die. To continue themselves, such parasites must either develop an impervious covering or enter the fluid-containing organs or tissues within the body of the host. For this reason the majority of ectoparasites found on terrestrial hosts are arthropods. In most cases the endoparasites have entered the host either through the oral or anal openings. Once inside the alimentary canal or one of its evaginations the parasite has found a veritable haven of refuge with a constant and abundant food supply. More often, however, when an aquatic animal leaves the water it loses its former parasites and acquires a new and different series of these predacious guests.

The adoption of the endoparasitic habit entails certain difficulties and dangers on the part of the species which assumes it. If the progeny of the parasite remains in the original host and continues to multiply there the life of the host is imperiled. Indeed, as Van Beneden long since pointed out,

> The parasite is he whose profession it is to live at the expense of his neighbor, and whose only employment consists in taking advantage of him, but prudently, so as not to endanger his life. He is a pauper who needs help lest he should die on the highway, but who practices the precept—not to kill the fowl in order to get the eggs. . . . The beast of prey kills its victim in order to feed upon his flesh, the parasite does not kill; on the contrary, he profits by all the advantages enjoyed by the host on whom he thrusts his presence.

The destruction of the host would be fatal to the parasite in question. In order that the parasitic habit may be successfully continued it is essential that the offspring of the parasite should leave the first host and secure new hosts, and incidentally this process of finding new hosts provides for the distribution of the species.

The life history of parasitic forms constitutes one of the most intricate and interesting subjects in the whole field of biology. As a rule, the parasite gives rise by reproduction to individuals which

pass out from the host. They may be cysts or eggs or larvae. These are the forms which constitute the infective stages in the life cycle of the parasite and which are concerned in the dispersal of the species. In certain instances, they reenter the original host species; in others, they attack different animals which serve as intermediate hosts. In any event, on leaving the primary host they are subjected to all the vicissitudes of a free-living existence. They encounter enemies and adverse environmental conditions. Frequently they are unable to take food and consequently must find a new host quickly or perish. Inadequately equipped to meet the exigencies of an independent existence, they largely succumb. The possibility that a particular larva will be able to survive and find a suitable host is extremely remote. Actually, in certain species not more than one in a million ever completes the life cycle. According to the estimate of Cort and his associates in the study of hookworm disease, each adult female produces on the average 8,830 eggs per day. In other nematode species, investigators report as many as sixty millions of eggs produced by a single worm. The liver fluke probably produces an equal number. On a conservative estimate, the beef tapeworm, *Taenia saginata*, produces 150 millions of eggs per year. In a balanced condition of nature, only a sufficient number of any species survives to replace the losses occasioned by death. Since the number of parasites remains relatively constant, each individual produces only one to succeed it. Obviously the mortality among parasitic forms is tremendous, and it is the hazard of the life cycle which introduces such disastrous consequences.

Frequently the dispersal stages of parasites are quite unlike their immediate progenitors. The Protozoa give rise to cysts, the Trematoda to ciliated larvae which resemble paramecia, and the Cestoda to microscopic six-hooked embryos. The protozoan cysts and tapeworm onchospheres are provided with resistant coverings and remain dormant, awaiting conditions favorable for development on the chance introduction into a suitable host. In other instances, the trematodes for example, free-living stages may be interposed. The parasitic stage produces a free-living one, which in turn either directly or by reproduction gives rise to individuals which infest the original host species or closely related forms. A third type of life history may be developed whereby the parasite is transferred from one host to the next by an intermediate host which acts as a carrier or vector. In this instance there are no resistant or free-living stages.

The complicated developmental cycles which exist to-day among parasitic forms can not be the original or primitive life histories of these species. In the long period of evolutionary development there have been innumerable changes in the relations between hosts and parasites. Former hosts have become extinct, and certain of their parasites, modified in form and life history, have passed on to new hosts; the hosts may have become parasitic; or serving as food for other animals they may have carried their parasites into these species, where they have become established. Such a history has led to alteration of hosts and the interpolation of additional hosts; to metamorphosis and to peculiar types of metagenesis. The complex, intricate series of stages found in many life histories afford evidence concerning the course of events during past ages and the manner by which the parasitic habit has developed; but the character of the evidence, the complications, additions, omissions and reversals render an interpretation exceedingly difficult.

The question of the origin and development of parasitic life histories is a perplexing one, while the evidence is

fragmentary, obscure and sometimes contradictory. The student of vertebrate phylogeny has four sources from which he can deduce the past history of a species. Comparative morphology, embryology, paleontology and geographical distribution all contribute data which can be utilized in the determination of previous history. The parasitologist, on the other hand, unfortunately, has fewer and less definite sources of information. He deals with forms that have undergone adaptive specialization for their particular mode of existence, and this adaption tends to destroy primitive morphological features. Paleontological records are of course not available, for with rare exceptions parasites do not possess hard parts that would be preserved in a fossilized condition. Even geographical distribution is of slight and questionable value since there are various means by which parasitic forms spread from one locality to another. It is then in the study of the life history, and comparison between structure of the parasite and closely related free-living forms, that most of the evidence must be obtained. In cases of extreme parasitic adaptation such evidence is scanty. Living under relatively constant, uniform conditions, representatives of different phyla assume a superficial resemblance that may mislead even careful and experienced observers. The well-known tendency for animals of diverse ancestry to converge toward the same morphological type after living for a long period in the same environment is especially prevalent among parasitic forms. The adaptations to parasitism accentuate the likeness, and if no free-living stages are present in the life history it is well-nigh impossible to trace the ancestry and evolution of highly modified types. Additional complications arise when parthenogenesis and pedogenesis are introduced or interpolated in the life cycle. With sexual maturity of one of the larval stages, the primitive adult form may disappear entirely, and such elimination of the ancestral type multiplies the confusion. Frequently it is difficult if not impossible to determine whether certain existing forms are primitive or pedogenetic. While the elucidation of many life histories is difficult and present opinions are admittedly tentative, in cases where parasitic species have closely related free-living relatives, or in which larval stages have a free-living existence, positive conclusions may be derived with reasonable assurance.

The analysis of a few life histories taken from representative groups will illustrate these principles. Turning to the simplest organisms, the amebae, we find several harmless species which live in the intestine of various animals. Morphologically and physiologically they resemble free-living forms. Their vegetative stages occur in the intestine, and encysted stages pass out of the alimentary tract to be accidentally ingested by other hosts. In nature it must frequently happen that encysted stages of free-living amebae are ingested by various animals. In the intestine they find decomposing organic material, a limited supply of oxygen, and other conditions similar to those found in the bottom of the pond. It is easily possible for such amebae to spend considerable time in this environment. Some of them may encyst, and these stages, lacking motility, pass out with the intestinal content. Such a series of events will give us one of the harmless intestinal amebae as, for example, *Endamoeba coli*. This species acts as a scavenger, creeping about on the intestinal wall, ingesting bacteria and intestinal débris. A further stage in the development of the parasitic habit is manifested by *Endamoeba histolytica*, the pathogenic ameba of man. This species attacks the wall of the intestine where it frequently causes extensive ulceration. It feeds on the cells and red blood corpuscles of the host and after penetrating the intestinal

mucosa may enter the blood vessels of this region. The amebae are carried by intestinal veins to the liver where they produce hepatic abscesses, and Kofoid has submitted evidence to show that they may be carried to other parts of the body, giving rise to one type of arthritis deformans, and possibly also to Hodgkin's disease.

A similar series of events may explain the evolution of the flagellates parasitic in the intestine of various vertebrate and invertebrate hosts. A further modification and more complicated life history has developed in the case of the so-called binucleate flagellates, transmitted by insects and parasitic in the blood and tissues of vertebrates. Probably the most important members of this group are the trypanosomes, causative agents of certain recurrent fevers and sleeping sickness in man, and several fatal infections in lower animals. It appears reasonably certain that the trypanosomes originally were parasitic in the intestine of insects. In their life history there are three stages which correspond to the genera, Leishmania, Herpetomonas and Crithidia, respectively. These three genera may be free living, may occur in the latex of plants, or be parasitic in the intestine of insects. The primitive insects probably lived on plants or their juices. Some of the more plastic flagellates originally found in water or upon plants became accustomed to live in the intestine of insects. Later when these insects began to feed upon meat juices and eventually on blood, the flagellates in their intestinal tract gradually came to live in a blood medium. Entomologists are agreed that the acquisition of the sanguivorous habit by blood-sucking insects is recent and secondary. The flagellates in the alimentary canal of the insect, regurgitated while feeding, accidentally were introduced into the blood of the vertebrate and multiplied asexually there. The insect harbors the sexual stages and is properly regarded as the primary host.

The flatworms manifest all stages of parasitic adaptation. Better perhaps than any other group in the animal kingdom, they exhibit a consecutive series of stages illustrating physiological and morphological degeneration together with a corresponding increase in complexity of life cycle. The planarians are free-living, carnivorous forms. It is but a step from them to the monogenetic trematodes. These latter worms have lost their cilia, developed posterior organs of attachment and become parasitic on the skin and gills of various aquatic vertebrates. Their life history is relatively simple. The hermaphroditic worm produces eggs, which remain for a longer or shorter period within the body of the parent. An embryo, similar to the adult, develops in each egg and sooner or later escapes to become parasitic on the original host species. The digenetic trematodes constitute a separate group, not closely related to the Monogenea. The sexual stages are endoparasitic, occur in the intestine or body cavities of vertebrates, and produce eggs—each of which contains a minute ciliated embryo known as a miracidium. In all cases so far as known, this larva becomes free swimming, enters a mollusk, undergoes metamorphosis to form a sporocyst, and by a series of parthenogenetic generations produces cercariae—larvae of a very different type. These second larval forms leave the mollusk and directly or indirectly reach the original vertebrate host where they become sexually mature. The life cycle just sketched is typical, although there is much variation in the group.

Consideration of the life history just traced raises one of the most difficult problems in biology—the origin, status and meaning of the intermediate host. Did the original trematode ancestors enter vertebrates and have a life cycle without the molluscan host as believed by Looss and Mordvilko? Or as advocated by Leuckart and Sinitzin, did they first become parasites of mollusks and

later attack vertebrates? Yet more unlikely, did they attack vertebrates and mollusks simultaneously? Is their parthenogenetic reproduction in the mollusk a secondary and recent interpolation in the life history, or is the mollusk the original host—now reduced to the position of intermediate host? When and where did heterogeny arise? Did the mollusk formerly harbor the sexual stages of the parasite, or were these stages free living? All these questions have been discussed by able students of biology, and much difference of opinion exists. Even among those authors who believe that the mollusk was the first to be parasitized, and present evidence tends to support such a view, there is lack of agreement as to whether primitively reproduction in the mollusk was sexual or parthenogenetic.

The culminating stage of parasitic adaptation in the flatworms is found among the cestodes. Although their morphological features indicate their relation to the trematodes, they constitute a much more highly specialized group. Typically the cestode, or tapeworm, consists of a scolex or adhesive organ, a zone of growth, and a series of proglottids or segments. In certain species one or more of these parts may be reduced or missing. At no stage of the life history is there any trace of an alimentary tract. Single nervous and excretory systems supply the entire organism, while the muscular and reproductive systems are serially repeated in each segment. According to Leuckart the tapeworm is to be regarded as a colony and each proglottid as an individual. Such a view appears extreme, but actually it is impossible at the present time to determine with certainty which was primitively the anterior or posterior end. With rare exceptions the sexually mature tapeworms occur in the intestine of vertebrates. They have no free-living stages, the eggs pass out from the alimentary canal and are ingested by an intermediate host, either another vertebrate or an invertebrate. Ordinarily there is no multiplication in the intermediate host and accidental reentry into the original host with food or drink completes the life cycle. In the tapeworms of herbivorous mammals no intermediate host has been discovered, although presumably one exists. The recent work of Joyeux has shown that in certain species an intermediate host is unnecessary. Since there are no free-living stages, the interpretation of cestode life histories is exceedingly difficult. The questions which were raised concerning the origin of parasitism and the evolution of life histories among the trematodes may appropriately be applied to the cestodes. We can only conjecture as to whether the original hosts were vertebrates or invertebrates and how present life histories have been developed.

The nematodes manifest different types of life histories, and a study of parasitic adaptation as it has developed among these forms entails many peculiar problems. They have no near relatives and constitute an isolated and aberrant group in the animal kingdom. There are a very large number of species, some of which are free living, others parasitic. Many of the parasitic species have free-living stages in their life cycle, and it may be either the larvae or the sexually mature adults that live an independent existence. Frequently heterogeny occurs and a parasitic generation alternates with a free-living one. Keilin has recently attempted to prove that the free-living forms have been derived from parasitic ones and that such a history explains their morphological and biological peculiarities. Baylis, on the other hand, derived the parasitic from the free-living species. The worms are usually diecious. Females liberate either eggs or larvae. Frequently the larvae go through successive molts. Some develop

immediately and directly, causing heavy infestation; others require one or more intermediate hosts. Representative types of development may well be cited.

One of the best-known life histories is that of the hookworm. This nematode occurs in tropical and semi-tropical countries throughout the world. Authorities estimate that over a billion people are parasitized by hookworms. It is only thirty years since Looss, in Egypt, worked out the life history of the worm. His report was received with much hesitation—the story seemed too much like a fairy tale—but subsequent researches have confirmed his results. The adult worms live in the intestine and thousands of eggs are voided daily with the fecal material. If conditions are favorable, development proceeds and in a day or two the embryos hatch and enter the soil. They molt at the end of the second day and three days later are ready to molt again, although they may live in the loose skin for several weeks. At this stage they are infective, and if a warm-blooded animal touches the soil in which they lie, the larvae leave their sheaths and bore through the skin and tissues until they reach the lymph vessels or veins. They are then carried by the vascular system to the heart and thence to the lungs. In the lungs they leave the blood capillaries, enter the air sacs, migrate up the bronchioles and trachea, pass over the epiglottis, down the esophagus, and through the stomach to the duodenum where the migration is ended. During the period of migration there are two additional molts. The time required for development from the infective stage to sexually mature adults varies from four to six weeks. In this species there is a single host, a free-living stage and no asexual or parthenogenetic reproduction.

Another important species from the medical point of view is *Filaria bancrofti*, which is prevalent in all tropical countries. Adults live in the deeper lymph vessels and the larvae pass into the vascular system. These young worms swarm in the peripheral blood during the night, and mosquitoes act as intermediate hosts. After a developmental cycle in the body of the mosquito the larvae pass to the salivary glands, ready to enter a human being whenever the insect feeds. In Filaria there are two hosts, no free-living stages and no asexual or parthenogenetic generations.

A third type of life history is found in Trichinella. Adults live in the intestine; the larvae are discharged into the blood stream, distributed over the body, and eventually encyst in the striated muscles of the same host. Transfer to a new host occurs when infested muscle is eaten. In Trichinella there is a single host, no free-living stage and no asexual or parthenogenetic reproduction.

In the three life histories just given and in others, notably that of Ascaris, nematode larvae make extensive migrations through the body and tissues of their hosts. Frequently they pass by way of the vascular system. Other genera, for example, Onchocerca and Dracunculus, live in the connective tissues and regularly move about. Periodically they come to the surface of the body and may be felt in the subcutaneous areas. It seems probable that the frequent occurrence of such migratory habits among distantly related forms is of deep phylogenetic significance, although the exact meaning is not at all clear. We have no assurance that among the nematodes the stages of ontogeny correspond to those of phylogeny, and more information must be available before a final interpretation can be given.

Study of the life histories found in the several forms reviewed emphasizes certain common features. In general, all endoparasitic species must have some means of transfer from one host to another and usually it is accomplished by free-living, encysted, or other larval

stages. There seems to be no morphological reason for such migrations; they are extremely hazardous, and the phenomenon is necessarily one associated with physiological and life history requirements of parasitic forms. It is possible, as advocated by Moniez, that there are rejuvenating effects resulting from change of host and life in a different environment. Whatever explanation may be advanced to account for the development of the complex life histories of parasitic forms, it is certain that the changes have come about gradually as adaptive responses to new conditions. For that reason life history studies are of prime importance in tracing past history in any species, and the examples cited demonstrate the significance of larval stages in the elucidation and interpretation of present developmental cycles.

Undoubtedly parasites have existed since earliest times, and to a large extent the original species or their descendants have survived. Consequently it appears inevitable that parasitic forms have changed their character and their hosts with the passing of time, and these changes are responsible for the diversity of life histories now found among them. In certain species the sexual stages probably remain in the original hosts; in others they now occur in more recently acquired hosts. In many cases the later parasites made their appearance or transformation hand in hand with the evolution of their hosts. The parallel evolution of hosts and parasites has been demonstrated by many authors. Kellogg's studies on bird lice gave the basis for a natural classification of their hosts, and more recently Metcalf has traced a similar relationship between the amphibians and their opalinid parasites.

As a result of the long period of parasitic adaptation and the modifications of life history, characteristic changes have been wrought in the structure of the parasites themselves. It has long been recognized that parasites are descended from free-living forms. Among certain groups, notably the ectoparasites, there have been only slight physiological changes and little structural modification. Among others, especially endoparasitic types, there have been enormous changes in habits, in function and in physiological requirements. Accompanying and probably resulting from these changes, the species affected have been so modified that in certain instances they no longer resemble their free-living ancestors. The adoption of the parasitic habit usually results in a progressive reduction of the structures which function most vigorously in a free-living existence. The organs which render a species most alert and active, no longer used, undergo atrophy. Especially is this true of the sensory and locomotor organs. The parasitic flatworms have lost their cilia, fleas and lice have lost their wings, the scab mites are without eyes or organs of respiration, and the linguatulids are so highly modified that they have lost practically all of their primitive characteristics and superficially resemble tapeworms. With the degeneration of the sense organs and the muscles, there is a corresponding reduction of the central nervous system. As parasitic degeneration proceeds, one after another of the organ systems suffers reduction and ultimately disappears. Certain groups, of which the cestodes are a conspicuous example, have lost all traces of an alimentary tract. With such stupendous changes in the organ systems, there are corresponding modifications of body form. The mites and ticks are flattened dorsoventrally, facilitating close adherence to the skin. The fleas are compressed laterally and more readily slip through the hair. Beginning with species manifesting such slight changes, it is possible to construct a parasitic series illustrating progressive modification of body form until finally

the original structure is entirely obliterated. Sacculina is the classic example of such extreme degeneration.

Compensating for the reduction and loss of the organs which functioned during free-living existence, parasites have developed new structures adapted to serve different needs inherent in the changed mode of life. One of the first requirements is organs for attachment to enable the parasites to maintain their position on or in the body of the host. Various types of adhesive appliances have been evolved, ranging from the sucking disk of Giardia to the powerful suckers and hooks of the monogenetic trematodes. In almost every group one finds some sort of suckers or hooks or both. Not infrequently the new organs arise through the metamorphosis of primitive ones. Among the worms, modifications of the body wall at particular places have resulted in the formation of suckers. The hooks of many arthropod parasites are merely the vestiges of former appendages. The forms which live in closed cavities may be without adhesive organs, but in certain species at least the absence of such structures is regarded as secondary.

It is uniformly true that the luxurious idleness of parasitism—an inactive life with abundant nourishment—results in a very great over-development of the reproductive organs. As the other organ systems undergo regression, all the results of an active metabolism find expression in enormously increased sexual activity. Trematodes and cestodes produce millions of eggs. The culmination of this tendency is found among those highly specialized forms which have lost all save the genital organs and have become mere reproductive machines. It is the enormous fertility of endoparasitic species that has enabled them to overcome the disadvantages imposed by their complicated life histories and the transfer or alternation of hosts. Other factors, it is true, assist in this regard. Resistant coverings protect the larvae during unfavorable conditions and accessory methods of reproduction arise. Hermaphroditism and parthenogenetic multiplication, frequent results of parasitism, increase the number of individuals and the probability of survival. Not only is there hypertrophy of the reproductive organs, but among species that have become greatly modified as a result of parasitism, frequently asexual multiplication occurs between the sexual phases.

The excretory system is less modified as a result of parasitism than is any of the other organ systems. It functions in the elimination of nitrogenous wastes of metabolism, and the sum total of metabolic activity is not greatly influenced by parasitic life. Instead of expending its strength in locomotion, food getting and the other activities of free-living forms, the parasite utilizes its energy in reproduction. Unless the body form is considerably altered, however, the excretory system is not appreciably affected. Consequently, since it is a primitive, deep-seated and conservative system, in many instances it serves as one of the best clues to the relationship of parasites, not only between themselves, but also with their free-living relatives.

That parasites have harmful effects upon their hosts has long been recognized. It is almost inconceivable that an animal could harbor large numbers of parasites without serious and deleterious consequences. The best general statement to be found in literature concerning the influence of parasitism upon the host is that of Professor Henry B. Ward, published in *Science,* February 3, 1907. The clear conception of fundamental principles there portrayed has been demonstrated by the results of the last twenty years, while the analysis and conclusions presented stand out in stronger relief to-day than when the paper was written.

A consideration of the subject will show that the effects of parasitism depend on certain general or primary factors. Two of these are the size and number of the parasites. Other things equal, the larger parasites are likely to produce the most pronounced effects, although because of the action of complicating factors, in many instances this is not the case. Usually the larger parasites are found in the larger hosts; consequently their size, relatively no greater, is of no more significance. Ordinarily the single parasite has little or no influence; the presence of large numbers multiplies the effect and renders them dangerous. Not infrequently several parasitic species may infest the same host. As a rule, the smaller parasites occur in the greatest numbers. Thus the degree of influence exerted by parasites is largely determined by their size and number.

The consumption of nourishment by parasites constitutes a third general factor concerned in their effects. If abundantly nourished, the host may not suffer great inconvenience due to the loss of food material taken by its parasites. It is only when the food supply is limited, and just sufficient to maintain the life of the host, that the support of numbers of parasites becomes a serious drain upon vitality. In undernourished children the presence of hookworms retards or arrests development to a serious degree. Individuals of twenty years of age may have only the physical and mental development of a child of ten. It is a common observation that the presence of large numbers of parasites inhibits the development of the sexual organs; or if the parasites are acquired in later life they may so reduce the vitality of the host as to induce parasitic castration. An interesting sidelight on this subject is afforded by observations made in our laboratories. When animals are kept for a considerable period without food, the parasites of their intestinal tracts, deprived of food material, are able to maintain life, but their sexual organs suffer regression and temporarily reproductive activity is suspended.

Another primary factor concerned in the effect of parasitism is the location of the parasites. No organ is entirely free from parasitic infestation. Parasites may occur in the central nervous system, the sensory organs, bones, muscles, connective tissue, alimentary tract, lungs, liver, heart and vascular system, excretory and reproductive organs. If they invade an inactive or passive tissue it is obvious that the effects will be very much less dangerous than when the brain or some other vital part is involved and affected. Certain large nematodes may live for years in the connective tissue without any perceptible ill effect, while microscopic trypanosomes in the cerebro-spinal fluid produce sleeping sickness and lead to fatal results.

The effects of parasites may be classed as mechanical and physiological, although these categories overlap to a considerable extent. Naturally, severe mechanical injury must lead to physiological derangement. For descriptive purposes, however, the two may be considered separately.

Mechanical injuries arise through the obstruction of various canals. The blocking of the alimentary tract or of the ducts which lead from glands may produce serious results; such interruption of function induces stasis in the organs, pressure and sometimes even rupture of the parts. The presence of parasites or their products in the blood vessels may lead to the formation of emboli. Such foreign bodies in the circulation may interfere with the proper action of the valves of the heart or may obstruct the smaller capillaries, producing aneurisms in the brain or other vital organs. In other instances, for example, filariasis, masses of embryos obstruct the lymphatics, resulting in stasis,

edema, the formation of abnormal lymph sinuses, the enlargement of the parts and the production of elephantiasis.

Frequently mechanical obstruction or the activity of parasites leads to the formation of various types of lesions. The parasites may feed on the tissues as in the case of *Endamoeba histolytica* or the liver fluke. The destruction of any considerable amount of tissue would lead to diminished function and serious disturbance of physiological activity. The irritation resulting from these lesions stimulates cell proliferation and not infrequently leads to tumor formation. The most serious effects of lesions, and especially those produced by the migrations of parasites through the tissue, are due to the introduction of pathogenic bacteria. It has long been known that the ulcerations of the large intestine produced by *Endamoeba histolytica* allow the passage of bacteria into the submucosa and the blood stream. A common complication is the formation of abscesses in the liver, lungs and other organs. The frequent passage of worms through the wall of the alimentary canal permits or induces the entrance of bacteria into the body cavity and sets up general peritonitis. Laceration of tissue allows the entrance of bacteria into the blood stream and may give rise to general septicemia. Although there are histological changes in host tissues and many other results that properly fit in this category, obstruction of canals and production of lesions constitute the principal mechanical effects induced by parasites.

The physiological effects of parasitism, aside from deranged function produced by structural lesions, are due in large measure to the elaboration of substances which have a toxic action on the host. Certain of these substances consist of the ordinary excretory materials elaborated by the parasites as a result of their metabolic activity. The liberation of large amounts of these nitrogenous wastes has a profound effect on the physiological adjustment of the host. Another group of harmful substances comprise the specific toxins which are produced by particular parasites and cause particular reactions in the host. It is the production by trypanosomes of toxic substances which gives rise to various recurrent fevers and to sleeping sickness. These active principles have been extracted from the bodies of various parasites, and when injected into living organisms produce effects analogous to the symptoms of actual infestation. Specific toxic substances have been recovered from many of the parasitic worms, notably Ascaris and Diphyllobothrium. The toxins produced by this latter worm give rise to a progressive and extremely pernicious type of anemia, often associated with marked nervous disturbances. Frequently there is a combination of these two types of substances, excretory wastes and specific toxins, and it is difficult to determine whether the reaction is due to one or the other or both. Such a condition arises at the end of the reproductive cycle in malaria when the red blood corpuscles are ruptured and the melanin substance is liberated in the blood stream. The material is ordinarily believed to be derived from the destruction of hemoglobin; although it undoubtedly represents both—specific toxic substances and metabolic wastes. An additional category of toxic substances are those produced by the death and disintegration of the parasites, by the anaerobic and fermentative decomposition of organic material. Not infrequently dead parasites are the most dangerous. The decomposition of the parasites may result in the formation of particularly virulent products.

The presence of these foreign substances in the body of the host leads to marked changes in the character of the blood. Certain of them destroy red blood cells; others induce different blood

changes. The nature of these substances and the method by which they act are as yet almost entirely unknown. One of the first recognizable effects is an increase in the number of eosinophile leucocytes, and the increased number of these cells in the blood corresponds with the intensity of infestation. Consequently, eosinophilia may be regarded as a diagnostic feature of parasitic infestation.

The substances elaborated by certain parasites cause such changes in the blood that its ability to coagulate is inhibited. The secretion produced by the salivary glands of hookworms prevents the coagulation of blood, and hookworm lesions in the intestine bleed profusely. Serious anemia may be caused by a half dozen hookworms, and a common test of hookworm infestation is to measure the amount of hemoglobin in the fecal material. By this means it is possible to estimate closely the number of hookworms in the intestine.

The factors involved in the degree of susceptibility and resistance to animal parasitism are as yet only partially understood. It is generally appreciated that young animals are more susceptible to parasitic infestations than adult individuals. It has been suggested that the older individuals are refractory because of resistance developed as a result of some previous infestation, possibly slight and unnoticed. Careful and controlled experiments have proved, however, that the age factor is of importance, irrespective of previous infestation. In test cases where prior history is known and it is certain that the subjects have not been previously parasitized, young animals may be infected while adults of the same species resist infestation. Young animals that are susceptible develop increased resistance to infestation as they grow older. The basis of this reaction is chemical, but we have no precise knowledge as to the factors concerned in the development of this resistance.

It is generally agreed that species or races which have harbored a given parasite for a long period of time show less marked effects as the result of its presence than species that previously have not been subjected to such infestation. In most instances, however, infestation by animal parasites does not give rise to immune reactions such as usually result from bacterial infection. Agglutinins, precipitins and lysins do not develop, or at least do not become effective for animal parasites. The immune substances developed in response to bacterial infections render such diseases self-terminating, whereas a parasitic infestation may persist for many years. Ordinarily an individual can be reinfested over and over again. In the case of animal parasites, defense reactions, comparable to those against bacteria, are not developed. It is certain that the blood is modified and that the presence of parasites may be detected by serological tests; but the study of defense and immunity phenomena has not progressed so far in the case of animal parasites as in that of bacteria, and the field of serological investigation is one of the most promising for future work in parasitology.

Parasitology is not, as has sometimes been supposed, a narrow or highly specialized field of study. It is, on the contrary, as wide and general as biology itself. The student of animal parasitology deals with every phylum from protozoans to mammals. No one can undertake an extensive study of any group, either animal or plant, without sooner or later encountering parasites and their effects. A consideration of parasitism, therefore, properly enters every field of biological inquiry whether the study concerns morphology, life history, physiology, ecology, pathology, genetics or evolution.

THE AWKWARD CONSISTENCY OF SCIENCE

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COMMON sense is the mother of Science. When the first philosophers ventured into a more exact inquiring into natural law than was necessary for mere existence, Science was born. Young Science discovered many things, none of them exactly true, usually things compatible with common sense. As Science became older, its laws became firmer and truer and stranger.

But even when learning its first faltering steps this infant, nursed by the philosophers, seemed a daring child. Not always were its theories the outgrowth of general knowledge. Sometimes they were the product of unbridled imagination. Such over-ambitious attempts to read the riddle of nature usually ended in fallacy. Many of the results of the earliest scientific speculations are buried in now forgotten mythologies; in later times the more daring adventurers in scientific thought conceived of astrology and alchemy and spiral cosmoses. The earliest adventures in extrapolation were unhappy.

But as Science has grown older and tried its laws have become more rigid and trustworthy, and it now ventures with much assurance into valuable extrapolations from the known into the unknown. As the scientific law has become reasonably sure the scientist bases his whole faith in it, and by consistent reasoning ventures into new theories of which common sense can never dream. Common sense is apt to classify things in a subjective manner. The fundamental concepts of common sense are things important to ourselves, such as three meals a day, the number of miles to a gallon and the price of soap; very important things to know about if we are to live happily. Science classifies objectively; the fuel value of gasoline and the affinity of molecules and the laws of electronic attraction are considered together as related concepts. Common sense teaches us that the sun rises once a day; science teaches us that the earth goes about the sun attracted to it by that same law by which the sun is (to a very unimportant extent) attracted to other suns. Common sense sees only the important; science recognizes only the consistent. The irresistible consistency of science often leads to concepts of nature from which our common sense revolts.

Common sense told our forefathers that the earth was flat, as of course for practical purposes it was; a slight change in the position of a star told the scientist that it was round, and Columbus discovered America. We all know that bodies fall down to the earth; Newton, treading the path of consistency, maintained that the earth also fell up to the body, and he explained the solar system. Common sense tells us that now is now whether we are moving or whether we are at rest; Einstein inquired as to the meaning of now and discovered relativity. Common sense tells us that a straight extension either of time or of space never retraces its path; the scientist is not so sure, and follows out his argument with a consistency which would be very awkward for common sense were common sense not fortified as always by its sublime consciousness of being right.

But let me illustrate by a simple example the fanatical consistency with

which the scientist follows his law. A reasonably sure law is Hooke's law of elasticity. If we have a metal bar and pull it, the harder we pull it the more it will stretch; bending it, the more the bending force the more it will bend. Good science and good common sense. If we have a steel railroad rail between two ties, the rail will undoubtedly bend as the train passes over it; with half the load the bend will be half as much; if we push it but gently with the hand it will bend, little, it is true, but still bend. Here common sense begins to hedge, but it is true. Such delicate instruments has science given us that even the slight touch of the hand produces an effect which is easily observed. Similarly, if a fly alights on the rail, it will bend. True the fly has but a billionth the weight of the car wheel and now the rail will bend but a billionth as much, but still it will bend. We do not really believe it but if one fly will not bend it, neither will two or three, nor can a train bend it. The difference is only between the important and unimportant. This illustrates what I mean by the awkward consistency of science; common sense neglects forces when too small to be important; science can only understand the larger force by remembering the smaller. The old soothsayer who first conceived of the straw which broke the camel's back had this consistency of the scientist.

The most famous propounder of awkward questions was Socrates, and indeed the difference in the point of view of the scientific observer of nature and the common user of nature is just the difference between Socrates with his annoying questions and the Athenian fish merchant with his edible merchandise. We may let a very modern Socrates be the spokesman for science and the fish merchant uphold common sense in a Socratic dialogue.

Socrates accosts his fellow citizen: I would a word with thee.

Fish Merchant: What do you think of fish to-day?

Socrates: Have you heard the latest word from the laboratory, that a fish is only a wave in space?

The fish merchant illustrates the new theory by continuing to fill space with his cries, Fish! Fish! Fish! But Socrates, being Socrates and utterly devoid of common sense, collars the fellow and the following dialogue ensues.

S. So you think a fish is only a fish; so as we look about we see many things which seem very simple. Before us we have a fish; it is an object and you know just where it is. Here fish, there no fish. It has its place in space where no other fish can be, it has weight and inertia and you know just where these are located. You think that no one but a foolish philosopher would cast doubt upon your knowledge of the existence of that fish. But the scientist, who is much better loved to-day than the philosopher, loves consistency no less than he and the scientist is indeed very much worried about just this question.

Now the fish merchant had spent all of his days in fishing and rather resented the superior knowledge which Socrates assumed to have in regard to the subject. When he had remarked as much, Socrates replied: Well said! Let us look then to a more neutral subject. Fish are but little favored in philosophic or scientific demonstrations. Consider a billiard ball on a table. I can specify its position very well by its center and so we will say that the ball is there. If the ball be gently pushed this center will change its position, going faster and faster. Were we to compare steel balls, iron balls and cork balls we should find that some balls gained speed more slowly than others; we say that they have more inertia or mass. This mass is just a number which we give to the ball to indicate the difficulty of moving its center; we need not worry for the moment about

where it is; it belongs to the ball just as your bank account belongs to you.

F. M. Now wait a bit, old man. That billiard ball isn't located at a mathematical point but is a real object, a sphere about an inch in radius. And its mass is located where *it* is.

S. I am willing to agree. It has more reality than an imaginary point near the table. It is an object and extends about an inch in every direction from the center of gravity. But how do you know?

F. M. I can feel it, I can handle it. Indeed so long as my finger is several inches away from your mathematical point the ball does in no way affect my finger; but let me come approximately an inch from it and the ball pushes back. Or if two similar balls were on the table those centers could never approach nearer than two inches. I say the ball is wherever it can affect other bodies.

S. Spoken like a philosopher and a scientist! A great philosopher once put forth as his only dictum *"Cogito ergo sum."* I like your definition of existence better. *"Facit ergo est."* It acts therefore it is. Your ball is wherever it acts. Where it exerts a force there it is. Or perhaps you would rather test it by sight; where it looks to be there it is.

F. M. No; let's leave the sight out of it. I know about your optical illusions. Feeling's believing.

S. Excellent; we can always tell where an object is by the fact that it exerts a force upon another body if it attempts to occupy that position. So much for common sense, now for logical consistency. Let us talk of lighter objects. What of water?

F. M. An object, but a stranger one. It does not keep the same shape. It will part and let my hand enter it and yet we can tell where it is by the same test. At some places my hand is not affected and at others my hand is pushed back. Wherever it acts there it is.

S. Excellent. And air? Is air something real or not?

F. M. A yet stranger object, but it is real.

S. Yes indeed. The test becomes more difficult. The ancients were not so sure of the materiality of a gas, hence the name gas or geist or ghost or spirit. Yet the presence of a gas is after all quite apparent—a rapid sweep of the arm meets resistance; a strong wind impresses us with the reality of this object. The mass is smaller, the object beats an easier retreat as we approach; yet it is very real.

But now, O worthy fish merchant, suppose I rub those billiard balls with a bit of wool; the balls now are electrically charged and the two similarly charged balls repel one another though their centers are many inches apart.

F. M. Yes, I have heard of this action at a distance and it has puzzled me greatly. How can a ball exert a force on another at a great distance from itself?

S. How, indeed? You tell me that a thing is wherever it acts and now you ask me how it can act where it is not! This is not a mystery of nature but a mystery of logic. Will you no longer cling to your meaning of existence? *Ubi facit, ibi est.* Where it acts there it is.

Oh the inconsistency of common sense! The ball pushes back on another ball; where it pushes there it is. The charged ball pushes back on another ball, but now it pushes where it is not. How strong must be the force before you believe in the reality of the object?

F. M. This is not the kind of push I meant. This electrical pushability of charged bodies extends in lessening degree everywhere; it is not the kind of force I meant. The existence of an object is betrayed by a suddenness of push when we touch it, which is very unlike this electrical force. Two inches away, an inch and a half, an inch and a hundredth, however little more than an inch away from the unchanged ball we are, there is no effect whatever; at an inch

distance the push suddenly begins. This is the space-occupying property which betrays the position of mass. That other kind of push is only the electrical field which we all know acts at a distance. The electrical field is too gentle, comes in too gradually, is too easily penetrable, to be a body; a material body always has a definite edge, at least always except in the case of gases.

S. An argument for the Sophists! You know where a body is, therefore it can not be somewhere else, least of all throughout all space! Well let it go for the moment. Now let me speak of something else of which I know more than you. All things, even fish, consist of molecules, atoms and finally of electrons and protons. Let us consider the least massive of all these, the electrons. An electron has mass; if it strikes a molecule or atom or other electron, it will push it back as a fast-moving ball does another ball. But these electrons are pure charge; they are like the charged billiard ball without the ball. They repel one another at great distances. The closer they come the greater the repulsion and this is all there is to it. Where are these electron objects? I should say, wherever they act. I should say that they extend in very unimportant intensity to the greatest distances in space. This is the awkward consistency of science.

But you do not want to consider this electrical force as locating the object. This is common sense. You want the electron to be where it "really is," not everywhere all over space where it isn't but happens to act. I do not understand. If this electrical repulsion is not a symbol of a real object to you we must agree that in your sense the electron is not an object because so far as we know this is the only force it can exert.

As with the electron, the elementary negative charge, so with the proton, its positive conjugate. And all atoms are made up of electrons and protons and all bodies are made up of atoms.

If a ball pushes back on your hand when you touch it, it is because the electrons or protons in ball and hand are repelling. Here as truly as in charged bodies the forces act at a distance, only the distances are very small, about a billionth of an inch. Beyond this the forces still exist, but they are really too small to be important. I am afraid if you do not accept these electrical forces as a symbol of the existence of an object that no object will for you ever exist.

What a dilemma! You don't believe that the thing you call ball extends, even in the slightest degree, everywhere. Yet where will you stop and say this much force makes an object; less than this is nothing? Oh the awkward consistency of science which insists on sticking to a definition!

At that the fish merchant winked and proceeded: It sounds philosophical but of course you and I both know it isn't so. We know that these balls are right there where they are.

S. In the important sense you are right. Most of the mass of the ball is right there very close to the electron and proton centers. The scientist sees all mass as electromagnetic and located about the charge centers, but even in the case of the charged ball where the electrical field extends to great distances the amount of mass in this external field is out of all proportion small in comparison to that between the multitudinous charges in the one-inch sphere. You certainly catch the most important part of the fish in your net. So you have the fish but I have the logic.

The fish merchant smiled a superior smile as though contented with this division and Socrates continued:

I see that you regard me as a hopeless philosopher arguing about the existence of nothing. You think my tenuous, all-pervading mass is of no consequence. But indeed without it all things are not. Let me mention another object which is equally tenuous, yet so important that

it can not have escaped your observation. I refer to light. Tell me again what you mean by a material body.

F. M. It is something which exerts a force when it is stopped; you can feel it when you punch it.

S. And so with light. It has little mass, it is true. Indeed so little that as I hold my hand out stopping the sunlight, I can not feel the pressure; but it is there. Perhaps you have seen in the jewelers' windows the radiometer, a device with vanes which rotate when the sun shines upon it. The action is complicated, but if all the air be removed from such a device and it be mounted more delicately it can be shown that light falling upon it produces a pressure, as does a ball striking a bat. If this is your test of materiality, and I believe it is the best possible one, light has mass. Very little, it is true, and yet some. All the light striking upon Greece during a minute of a summer day has a mass of about one ounce. It comes so fast that the total pressure it produces is considerable—about a quarter of a ton. The sun is continually losing mass—millions of tons per second—as it gives off light. Because of this light pressure, the tails of comets are seen to be pushed always away from the sun. Yes indeed, light does produce a push when it is stopped, and so it is material. Of course this pressure is too little to be felt by the hand and so all this is contrary to common sense. These things seem unimportant; as to what its fundamental significance is in the building up of universes you must ask the astronomer and perhaps he will tell you that nothing is more important.

F. M. That may be so, but sunlight is certainly not material just the same. Indeed, it fills all space where we know there is nothing. And if it be something why should it not fall back to the sun by gravitational attraction like everything else?

S. It does fall back but not very much. As it leaves the sun it loses some of its speed. But so great is its speed that it has no difficulty in getting away. Experiments several years ago to test the theory of relativity showed that starlight in spite of its high speed, was bent by attraction as it went by the sun. Again and again science following consistency faithfully reaches results which are contrary to common sense.

Were there time, I could tell you about the conservation of mass, how the moving electron grows heavier as it takes mass out of the field which makes it move, how stopping it gives off light and loses mass. I could tell you of some of the mysterious motions of this mass field in the atoms. I could tell you how science makes a consistent cosmos out of wave motions in space.

F. M. Well, goodbye Mr. Socrates, and it has been interesting; but just as between your mass and mine, yours may be as flighty as you wish but mine is all here.

With that the fishmonger went down the street selling his wares, and the modern Socrates went back to his problem of making artificial light more economically.

THE SPOOR OF A THUNDERBOLT

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Most normal American males have experienced in some degree the thrill of following a trail through the wilderness. The boy scout has as a specific assignment tracing the course of a companion wearing "tracking irons." The trailing of small game through the snow is an annual delight to the country lad. Following the spoor of big game is something most of us read about enviously, though few of us are able to do it. But it is a rare opportunity that permits a man to follow through the forest the trail of a flash of lightning for a distance of eighty-five feet, over rocks, sod and soil, through underbrush and dead timber, from near the top of a hill to the shore of the lake at its base.

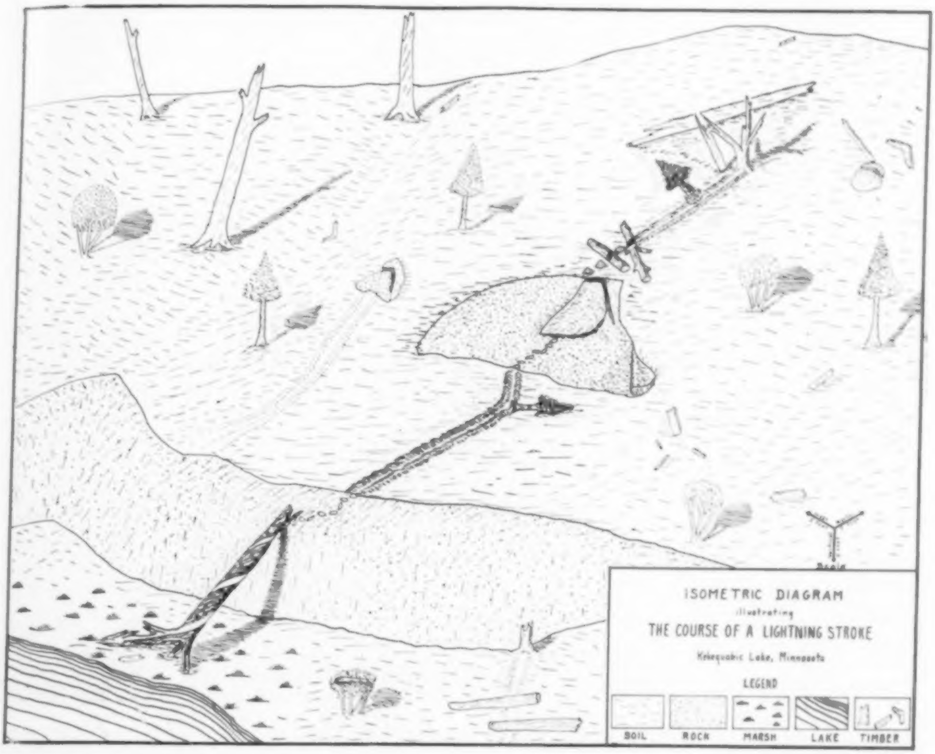
Such an opportunity was unexpectedly encountered by a party of Northwestern University geologists, under the leadership of Professor U. S. Grant, while in their summer camp on Kekequabic Lake in northern Minnesota. The region is one of numerous lakes, separated by low hills, some of which, however, are steep and rugged. These hills were formerly clothed with a dense growth of pines, but forest fires have killed the big timber; at present the hills have a thin soil cover that supports a rather dense undergrowth. The remnants of the older forest consist of charred stumps, fallen logs and a relatively few standing trunks, now dead, twisted and bare of bark, some of them projecting as much as fifty feet above the undergrowth.

An island in Kekequabic Lake escaped the later fires, and on this wooded island the party camped. The hillside to the north of the lake is as described above; it was of particular interest to the geologists because the deforestation had resulted in several splendid rock exposures which under forest conditions would probably have been buried by soil and vegetable mold.

A dead tree standing near the top of the hill was the "lightning rod" that led the electric discharge from the clouds to the ground. Unfortunately, the lightning was not seen to strike, but its time can be fixed within forty-eight hours. On a Tuesday two members of the party had found some very interesting rock exposures on the hillside, and had noted a prominent dead tree to serve as a landmark. On Wednesday and Thursday the whole party was working at the west end of the lake, and both these days were marked by intermittent thunderstorms. On Friday the entire party went to the north side of the lake to observe the features noted on Tuesday, and were puzzled by the absence of the landmark; it was found that the tall dead tree had been completely wrecked by a lightning stroke on one of the preceding two days.

The accompanying photograph shows the shattered stump and the fallen trunk beside it. The ground was disturbed from the base of this stump down nearly to the lake shore, but much of the line of disturbance was obscured by underbrush so that it could not be photographed. Therefore the accompanying sketch has been prepared, based on photographs and measurements, but drawn so as to show the features by which the course of the lightning could be traced, without including the obscuring underbrush.

The tree that was first struck was shattered near the bottom as though by an explosive. The standing stump, nine



feet high, was split and riven to the core, but with pieces six feet or more in length flaring outward from the middle, but not completely broken away. A portion of this tree some thirty feet in length lay prone on the hill alongside the shattered stump; this fallen log was badly scarred and split, though not so completely shattered as was the standing stump. On the ground nearby lay numerous fragments of newly split wood, and such perfectly fresh chips could be found in diminishing numbers to a distance of nearly a hundred feet in all directions.

From the base of this stump and extending for sixteen feet directly down the hill, was a freshly turned furrow, about the size that would be made by a standard plow; a small pine tree about six feet high had stood at the edge of this furrow, and had been half uprooted and completely overturned to the west. At the lower end of this furrow were two logs, lying across its course; in line with the extension of the furrow these logs had been freshly charred on the surface. For six feet farther on small blocks of rock showed a distinct line of disturbance.

These small rock blocks, which had been moved from six to twelve inches out of their places, formed the somewhat broken upper surface of a bedrock exposure that extended about twenty feet down the hill and much farther than that along the hillside. At the lower end of the line of broken small blocks, a large block, measuring two by three by five feet in greatest dimensions and weighing something over a ton, had been moved bodily a distance of four inches to the south. At the upper end, where this block was thickest, it showed a clean break, and at the lower end, where it tapered down to an edge, it projected over the bedrock surface.

VIEW LOOKING WEST ACROSS KEKEQUABIC LAKE

SHOWING ISLAND ON WHICH PARTY CAMPED; THE NORTH SHORE OF THE LAKE, SHOWN AT THE RIGHT OF THE PICTURE, WAS THE SITE OF THE TREE THAT WAS STRUCK BY LIGHTNING.

The upper surface of this moved block showed no trace of the lightning effect, but from under the lower edge there were two lines of disturbance; about six feet southeast of the edge of the moved block the bedrock disappeared under a thin covering of soil, which a thick growth of grass and moss had knitted into a compact sod, resting directly upon the rock. This sod carpet, still showing fresh on the under side, had been folded back over an area measuring three by five feet, much as a rug might be folded double by pulling back the corner; this folded-back sod marked the end of the trail in this direction.

The main trail of the lightning went from under the edge of the moved block directly downhill, where for a distance of eight feet the surface of the bedrock was chipped and flaked, exposing patches of fresh rock that made a marked contrast with the weathered and moss-grown rock surface. In the loose soil farther down the hill was another furrow, perfectly fresh and but slightly smaller than the furrow that began at the base of the stump farther up the hill.

This lower furrow ran for about six feet southeasterly to the base of a small pine tree, which was overturned to the east; the furrow continued directly down the hill (nearly south) to the top of a fifteen-foot cliff that stood above the marsh at the edge of the lake.

In this marsh was a dead tree about eighteen feet long; this tree had fallen back against the cliff, a rocky projection of which had caught the tree about two feet below its top. From the lower end of the lower furrow, described in the last paragraph, to the point where this tree

rested against the cliff was a line of freshly broken and chipped bedrock quite similar to that seen on the rock above. The tree was scarred spirally in a striking manner; from the point where it touched the cliff the lightning had evidently followed the grain, and in this species of tree the grain is much twisted. A band of freshly scarred wood passed three times around the tree in the sixteen feet that lay below its resting point; the two feet above the point of contact with the cliff was not scarred at all. The contrast between this white scarred surface and the gray weathered surface of the wood was so marked as to give the tree something of the striped appearance of a barber's pole.

The grain that was so scarred was in line with one of the larger roots that remained buried in the bog. At the point where this root entered the bog, it again appeared that an explosion had occurred. The root was completely shattered, and apparently burst from the inside outward. Here, it seems, the lightning flash was finally grounded, after passing over rock, wood and soil for a distance of eighty-five feet from the base of the shattered stump first struck.

On first observing some of the disturbances on the lower part of the hill, one found difficulty in believing they were due to the same lightning that struck the tree above, but after tracing out the whole course, foot by foot, no doubts remained. The observer was left with a new appreciation of the tremendous power manifested by a lightning flash, and with a profound respect for the term "thunderbolt." This term, still sanctioned as good usage in describing a flash

VIEW LOOKING NORTH ACROSS KEKEQUABIC LAKE

SHOWING ISLAND ON WHICH PARTY CAMPED, AND BEYOND THE ISLAND THE HILL ON THE NORTH SHORE ON WHICH WAS FOUND THE SPOOR OF THE THUNDERBOLT.

PHOTO OF TREE THAT WAS STRUCK BY LIGHTNING

NORTH SHORE OF KEKEQUABIC LAKE; THE PATH OF THE LIGHTNING STROKE WENT CLEAR ACROSS THE GROUND SHOWN IN THIS VIEW, AND MOVED THE ROCK BLOCK, SHOWN AT THE EXTREME LEFT, A DISTANCE OF FOUR INCHES.

of lightning that strikes the ground, is a relic of the time before Franklin announced that lightning and electricity were the same thing, when "the notion prevailed that a solid heated mass passed along the lightning flash and buried itself in the ground." (Standard Dictionary.) The term "bolt" as used in those days did not have its present acceptation; but rather signified an arrow or projectile; in to-day's language "thunderbullet" would better express the original meaning.

If some philosopher of Franklin's time, before the performing of the famous kite experiment, could have been transported to the north shore of Kekequabic Lake to see what the writer has described, he might have speculated at length on the character of the thunder-projectile. Was it like a great axe, as the tree at the top suggested? Was it like a plow, to turn up furrows that were straight and deep? Was it like a wedge or lever, to pry a ton block of rock loose from its place? Was it like a chisel, to chip and flake the bare rock surface? Or was it like a roughing plane, to follow the grain around the tree at the bottom of the hill? Certainly, it looked as though something solid had passed through and torn things up; it is small wonder that it took a long time for men to recognize the relationship between lightning and the galvanic battery.

The observer of to-day, used to electricity as a commonplace factor of his daily life, is also led to speculate, but along a different line; he asks, How could the passage of the electric current

produce such effects, and why should the current follow that line, instead of being grounded at the base of the upper tree? The following explanation seems both simple and satisfying.

Electricity is known to pass along the line of least resistance. A lightning rod, a spire or a tree that is struck is a better conductor than is the air. Dry wood and dry earth are poor conductors; moist wood and moist earth are better, and consequently when a conductor is once grounded no further effects are generally visible.

The hill north of Kekequabic Lake, however, is composed of solid rock, except for a thin soil cover over part of it; this soil cover, moistened by the recent rains and partly dried at the surface by the intermittent summer sunshine, would furnish an interrupted layer of moist earth on the surface of the bedrock that would be a better conductor than the bedrock itself, and consequently would lead the electric charge downhill instead of directly into the earth at the first point of grounding.

This suggests an explanation for the unusual course of the current, but what about the character of the disturbance? Again the explanation seems simple and logical. Moist wood or moist earth, while the best conductors on that hillside, must still be ranked as poor conductors in comparison, for instance, with metals. Whenever electricity passes through a conductor it generates heat, and the poorer the conductor the greater the heat generated by the passage of a certain current. The generation of considerable heat in a moist medium would naturally transform that moisture into

PHOTO SHOWING ROCK BLOCK

WEIGHING BETWEEN ONE AND TWO TONS, MOVED A DISTANCE OF FOUR INCHES BY A LIGHTNING STROKE.

steam, and the expanding steam would seem to account for the exploded appearance already mentioned. The tree first struck, dried at the top by the suns of many summers, would naturally show greater explosive effect at the bottom, where it was partly shaded by the underbrush; the moisture at the bottom of the soil, leading the current downhill, would generate a steam pressure upward, apparently quite adequate to lift forcibly a foot or two of soil and produce furrows; the expansion of moisture in the preexisting cracks would move the ton block easily enough; the steam generated beneath the sod would blow back the sod-carpet as surely as steam blew off the lid of James Watt's kettle when the spout was plugged; the moisture in surficial cracks would blow off the chips and produce the flaked surfaces on the exposed bedrock, and the moisture following the twisted grain of the lower tree would have no difficulty in blowing off the weathered surface when vaporized suddenly.

When this explanation suggested itself, a further search of the hillside indicated that the case described was not unique. Other furrows, somewhat subdued by rainwash and vegetable growth, were found; other trees were found shattered, and other rock blocks moved from place. In none of these, however, were the evidences as fresh as in the case described. It seems improbable that the same line will be followed again by lightning, as other trees, still standing, will probably draw the charges in later summers, but similar conditions may be looked for where the immediate grounding of the lightning charge is difficult. Repeated occurrences of the same sort would be quite effective in helping to break up the rock surface and supply material for a new soil cover for this hillside; locally the geological effects of lightning seem more important than they have hitherto been considered.

The schoolboy, writing a composition, seems to have spoken more truly than he knew when he said "The reason why lightning never strikes twice in the same place is because after the lightning hits it, it is never the same place again."

THE PROGRESS OF SCIENCE

AWARD OF THE NOBEL PRIZES IN CHEMISTRY

THE fruits of research to-day are difficult of award. No longer does the worker retire to cell or laboratory for solitary labor and later emerge with an epoch-making discovery that is all his own. Communication has been facilitated and even workers in remote countries keep closely in touch with one another's problems and progress. It is an age of cooperative effort.

The Nobel chemical awards of 1927 and 1928 are examples which emphasize the difficulty of separating individual effort and recognition from the efforts and merits of others who have toiled in the same field. To some, familiar with the tremendous strides made by American scientists toward the solution of the problem of rickets, its cause and prevention, it came as a surprise when Stockholm announced that the Nobel prize in chemistry for 1928 was awarded to Professor Adolph Windaus, of Göttingen University, for explanation of the nature of the provitamin (ergosterol) which becomes rickets-preventing vitamin D when irradiated with ultra-violet rays.

Some, misunderstanding its basis, even resented it as a reflection on the work of Hess, Steenbock, Howland and others in this country or as ignoring the work of Rosenheim, Webster and Barger in England.

The 1927 award to Professor Heinrich Wieland, of Munich, for his work on bile acids and the origin of cholesterol was recognized as a logical tribute to specific work in a given field, but some have puzzled as to why the accounts linked these two names, Wieland and Windaus, together as having relation to vitamin studies.

In 1919, Mellanby, of England, set forth the hypothesis that the cause of rickets was a deficiency of vitamin A. Between 1919 and 1924 we saw the hypothesis negated. We saw two groups of American scientists initiate and carry out the experiments necessary to postulate and prove the existence of the true rickets-preventing vitamin D. We saw two men, Steenbock and Hess, demonstrate that irradiation of living animals or foodstuffs with the ultra-violet light will create this vitamin in inactive materials. To-day we have irradiated foods to help in our defense against this disease, and lamps to produce the healing rays are multiplying in type and numbers. But the problem of what vitamin D is was still unsolved.

The search went on. Cod-liver oil, its richest natural source, was fractioned. Where the fat was turned to soap the vitamin activity remained in the nonsaponifiable fraction. This result narrowed the chase. In 1924 Hess irradiated one of the components of this active fraction (cholesterol) and obtained a rickets cure. It looked like the end of the hunt. Trouble with this simple solution, however, soon developed. Hess's active crude cholesterol was in turn separable into a pure inactive cholesterol and an active residue.

Cholesterol isn't the only sterol. In England Rosenheim ran through a series of other sterols, using the violet ray and test animals. Barger and Webster cooperated, and a sample from ergot developed exceptional activity.

Now we come to Windaus' share in the problem. Twenty-five years or more he had been laboriously studying these sterol compounds. In all the world none knew better than he their character and properties. To him Hess wrote of his perplexities and urged him to turn his knowledge to help with identification.

PROFESSOR ADOLPH WINDAUS
OF THE UNIVERSITY OF GÖTTINGEN

PROFESSOR HEINRICH WIELAND
OF THE UNIVERSITY OF MUNICH

BUST OF PRESIDENT HERBERT HOOVER

PRESENTED BY MR. C. A. FISHER, CONSULTING GEOLOGIST AND ENGINEER, OF DENVER, TO THE AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS AT THEIR ANNUAL MEETING ON FEBRUARY 19. LEFT TO RIGHT STAND ELMER A. SPERRY, PRESIDENT OF THE SPERRY GYROSCOPE COMPANY; FREDERICK W. BRADLEY, PRESIDENT OF THE INSTITUTE; GEORGE OTIS SMITH, DIRECTOR OF THE U. S. GEOLOGICAL SURVEY AND PAST PRESIDENT OF THE INSTITUTE, AND DR. GEORGE F. KUNZ. MR. HOOVER IS PAST PRESIDENT AND HONORARY MEMBER OF THE INSTITUTE. THE BRONZE BUST IS THE WORK OF MRS. D. W. LEYS, OF YONKERS, N. Y., DAUGHTER OF MR. FISHER.

To him the English workers brought their ergot product for interpretation. The master in the sterol field demurred at first. He was interested in sterols, not in vitamins. After some time spent in persuasion he turned his experience to the task.

To-day we owe to him definite proof that the ergot sterol is a definite chemical entity, as separate from all other compounds as is salt. We owe to him the suggestions that led to tests on other sterol types and their elimination from potential precursors of vitamin D. His intimate knowledge of sterol chemistry has become a means to further research which may explain what exactly happens to ergosterol when the violet rays impinge.

If we may use a homely analogy, Windaus has been the key man in the team playing in a given contest, the "Poe" of the winning combination. His exaltation casts no dishonor on his team mates, and he has himself been quick to accredit those who consulted him for what they accomplished. May we not then rejoice that the judges had the discrimination, among so many claimants to distinction, to pick this key man as the one signally to honor.

What of Wieland and vitamins? Windaus pursues cholesterol and sterol chemistry. Wieland turns to cholic acid and evolves an explanation of cholesterol formation in the liver. We now know that cholesterol isn't provitamin D, but none knows how soon Wieland's work on cholesterol may provide the key to the metabolism of ergosterol—another example of the value of patient, thorough research.

To workers in other fields the relationships in a given field are often obscured. This tribute to two great chemists is penned to help if possible the understanding of why the Nobel honors are richly deserved.

WALTER HOLLIS EDDY

PRESENTATION OF A PORTRAIT OF DR. GEORGE ELLERY HALE TO THE NATIONAL ACADEMY

AT the annual meeting of the National Academy of Sciences in 1927 Dr. W. H. Welch presented the following resolution, which was adopted, and Dr. A. A. Noyes was appointed chairman of the committee to take care of the details in the matter of funds and the presentation of the portrait:

Resolved, That the National Academy of Sciences, earnestly desiring to possess a portrait in oils of its fellow member, George Ellery Hale, as a permanent memorial and an adornment of the walls of the fine building which it owes in large measure to his unselfish and untiring efforts in furthering the material and intellectual interests of the academy these many years and whose preeminence in science, universally recognized throughout the scientific world, have added distinguished honor likewise to the academy, requests Doctor Hale to sit for a portrait, to subscribe for which will be counted a pleasure and privilege by members of the academy and by friends and admirers. While the academy must respect limitations imposed by considerations for his health in calling for added services, even if associated with the highest honor in its power to bestow, it rejoices that it may look forward, it is confidently hoped, to many years of useful service restrained only by such consideration: Therefore, be it

Resolved, That the president be authorized to appoint a committee empowered to act upon this request.

In conveying to Doctor Hale this request the academy desires to accompany it with an expression of its grateful appreciation of his services, with felicitations upon a record of signal achievements in science, to which further contributions may be expected, and with its cordial and affectionate greetings and its best wishes for continued and vigorous activity and usefulness.

The report of the academy for the present year states that at the annual meeting Dr. Noyes gave a brief summary

DR. GEORGE ELLERY HALE
FROM THE PAINTING BY SEYMOUR THOMAS.

of how the committee secured the funds for a portrait and how they were particularly fortunate in securing Seymour Thomas, the portrait painter, who was at the time residing in Pasadena, to consent to paint the portrait in Dr. Hale's laboratory. The curtains on the speakers' platform were then drawn aside and the portrait was before the academy for acceptance.

The following communication from Dr. Hale was read:

It is impossible for me to express in adequate language my appreciation of the great and wholly unexpected honor done me by the academy. The resolution presented last year by my old friend Doctor Welch, though far too generous in its terms, touched me deeply. The truth is, of course, that I am only one of many men sincerely devoted to the academy and anxious to see its boundless possibilities fully utilized in the interests of science. I have taken great pleasure in its service and deserve no further reward.

Our national charter, as Elihu Root saw so clearly more than 15 years ago, when he became our close friend and wise counselor, has been the chief source of the academy's progress. Its potentialities have as yet been but partially realized, and I am confident that their further study and utilization will lead to great advances in the future.

Gentlemen of the academy and friends of many years, I thank you most cordially and sincerely, and assure you of my desire to work, to the extreme limit of my capacity, in the service of the academy and the advancement of science and research.

Dr. T. H. Morgan, the president of the academy, then said:

The original motion and its execution call for no further official action unless it be to release the committee and express our obligation to them. Nevertheless, I announce the formal acceptance of the portrait of Doctor Hale as a token of our appreciation of all he has done for the welfare of the academy and of the research council, and of our admiration of him as a great leader of science and of our affection for him as a fellow member.

THE "DANA" EXPEDITION

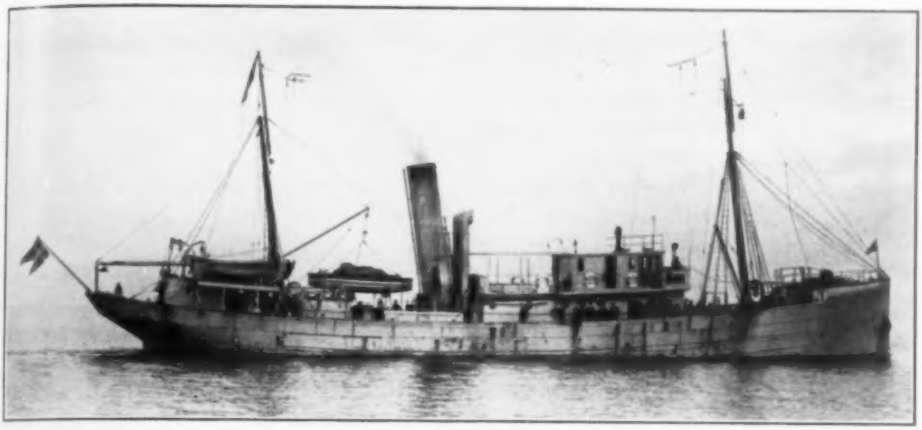
THE *Dana*, the research vessel of the Danish government, has embarked on a two-year voyage, primarily to study the natural history of the eel. Within the last twenty-three years Denmark has sent out five such expeditions. The itineraries were planned largely with a view to unravelling the habits of this apodal fish which had puzzled specialists in the field of ichthyology.

The vessel has been provided by the Danish government, but the costs are defrayed primarily by the Carlsberg Foundation at Copenhagen. Among those on the scientific staff are Drs. Johannes Schmidt, who has long devoted himself to the study of the natural history of the eel, Th. Mortensen, Ove Paulsen and J. N. Nielson.

The projected cruise of the *Dana* is outlined on the accompanying map. The vessel went first to Spain and the Mediterranean; then *via* Madeira to the West Indies and on through the Panama Canal into the Pacific, to Tahiti, the Fiji Islands and New Caledonia; thence to New Zealand and Eastern Australia. Two months were spent in the waters east of Australia, and the vessel is now proceeding northward to Japan and China. Later the Malay Archipelago will be visited (Dutch Indies, Siam, etc.), and investigations will then be made in the Indian Ocean along a line from Java to Madagascar. From Madagascar the course will lie along the East Coast of Africa, and through the Red Sea and the Mediterranean. The expedition is expected to terminate in the spring of 1930. The *Dana* is equipped with the most modern apparatus for the various forms of deep-sea fishery investigations, together with the most recent instruments for hydrographical observations. Throughout the voyage soundings will be taken with an echo-sound-

ALEXANDER A. MAXIMOW

FORMERLY PROFESSOR AT ST. PETERSBURG AND FROM 1922 UNTIL HIS DEATH PROFESSOR OF ANATOMY AT THE UNIVERSITY OF CHICAGO.



THE GOVERNMENT RESEARCH SHIP OF DENMARK

ing machine. The vessel is in constant direct communication with Copenhagen by means of a short-wave transmitter.

Eels are found in almost all the fresh waters of the temperate and tropical zones, but they do not breed in fresh water. Eggs and larvae have only been found in sea waters, and the fact has now been established that the young eels make their way up from the sea into the rivers and lakes. Here they live until they descend the stream into the ocean, where they spawn and die.

Before the Danish expedition of 1905–06 it was commonly believed that the breeding grounds of the eel were in the Mediterranean, but at that time extensive evidence was gathered to prove that the eels of both Scandinavia and Western Europe came from the Atlantic. Later it was discovered that the eels made their way through the Straits of Gibraltar and that they did not breed in the Mediterranean. Then the interesting observation was made that the eel larvae became more numerous and were smaller

THE ROUTE OF THE *DANA*

in size as one moved eastward across the Atlantic, which was evidence that the breeding of the eels took place in the western part of the ocean.

Then the striking discovery was made that all the eels of Europe spawn only in a small, restricted area of the western Atlantic in the vicinity of the West Indies. The larvae migrate across the ocean and about three years after hatching they make their way into the fresh waters of Europe and Northern Africa. The breeding ground of the American eel was found to be in approximately the same location. These larvae take only one year instead of three to reach the "elver" stage and begin their ascent into the fresh water rivers and lakes of North America. The chief distinguishing feature between the larvae of the American and the European eel is that the former has about eight less vertebrae in its backbone.

A few years ago certain Danish investigators working in conjunction with the International Council for the Investigation of the Sea tagged eels to ascertain the number of miles covered during the migratory period. The records of recapture are most interesting. The rate of migration was found to be about ten miles a day. One particular eel covered a distance of seven hundred and fifty miles in ninety-three days.